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MUNICIPAL USE OF GREEN STORMWATER INFRASTRUCTURE IN THE DELAWARE RIVER BASIN:

BARRIERS, DRIVERS, AND OPPORTUNITIES FOR IMPLEMENTATION

A Thesis in

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Abstract

Green infrastructure has recently emerged as an alternative to traditional gray infrastructure for managing stormwater runoff in urban settings. Green stormwater infrastructure offsets several of the urban environment's negative impacts on stormwater by reducing peak flows, filtering out contaminants and pollutants, and recharging groundwater aquifers by reintroducing natural systems and processes. In addition to improving urban hydrology, green stormwater infrastructure has also been shown to provide numerous environmental, economic, and social benefits that traditional gray stormwater infrastructure lacks.

The goal of this research is to assess perceptions of green stormwater infrastructure in 12 municipalities in the Delaware River Basin based on the opinions of directors of public works departments and other municipal employees with similar responsibilities as expressed during open-ended interviews. Drivers for, barriers to, and other aspects in regard to the implementation of green stormwater infrastructure are identified. The opinions of the participants are compared to opinions expressed in the existing literature focusing on green stormwater infrastructure as an alternative to traditional gray stormwater infrastructure. Conclusions are drawn with a focus on making recommendations to encourage local municipal government the use of green infrastructure in managing urban runoff, which will, in turn, reduce the urban environment's negative impacts on one of our most precious resources: water.

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Chapter 1

Introduction

Since the middle of the 20th century, there has been a steady effort to restore water quality in the Delaware River Basin. A stronger knowledge of the severity of water-quality issues, coupled with stricter rules and regulations put in place by the United States Environmental Protection Agency (EPA) and the Delaware River Basin Commission (DRBC), have brought watershed-scale efforts to bear on reducing the amount of point-source pollutants entering one of the United States' earliest colonized water bodies. Consequently, water-quality conditions have improved considerably since the Delaware was pronounced "a dead river, as dead as any in the United States" in the mid-20th century (Kauffman, 2010, p. 447).

In the 21st century, the greatest threat to water quality in the Delaware River Basin is non-point source pollution, namely urban stormwater runoff (Kauffman, 2010; Madden, 2010; PWD, 2011). In addition to transporting pollutants and reducing water quality, traditional gray stormwater management has also been shown to greatly vary the flow rates of tributaries in watersheds (Alberti, 2009; Girling & Kellett, 2005; Hough, 2004). Rainwater is diverted from the urban environment, rather than being used on-site; therefore establishing alternative sources for potable water is deemed necessary and has created a stringent demand on the regional water supply (Alberti, 2009; Hough, 2004). Residents may feel this impact most directly in the form of flooding, but the stressors on water quality, quantity, and flow have a lasting impact on ecosystems that depend on clean and stable water sources in the Delaware River Basin.

Green infrastructure has emerged as an alternative to traditional gray infrastructure given that the former has the potential to address the negative impacts of the urban hydrology cycle. Green stormwater infrastructure techniques focus on softening the negative impacts of traditional

stormwater infrastructure through the use of vegetation, retention, infiltration, and other natural processes. It has also been shown that green stormwater infrastructure offers numerous additional environmental, social, and economic benefits that traditional gray stormwater infrastructure does not offer to local ecosystems.

Philadelphia, the Delaware River Basin's largest urban center, in terms of both population and urbanized area, has made a strong effort since the early 21st century to incorporate green infrastructure into its stormwater management practices in order to alleviate the stress on its aging stormwater infrastructure. Though Philadelphia had been a major contributor to degraded water quality, due to its combined sewer overflows, it represents only a small fraction of the urban land in the Delaware River Basin. For centuries, hundreds of other towns and cities have lined the Delaware River and its tributaries, and the stormwater infrastructure has degraded the quality of the water for almost as long.

This thesis focuses on understanding the role of green stormwater infrastructure elsewhere in the Delaware River Basin based on the position that green stormwater infrastructure is a positive alternative to traditional methods of stormwater management. Twelve individuals, each an employee of a different local government participated in open-ended interviews and described their communities' current stormwater management systems, their opinions in regard to the use of green infrastructure within their communities, and their views of the role of green stormwater infrastructure in the future of their municipalities.

The interviews are analyzed through open coding and qualitative analysis in order to find common and contradictory opinions pertaining to stormwater infrastructure. The drivers of and barriers to implementing green methods expressed by the individuals are identified and related to similar findings in relevant literature. This research is intended to contribute to the knowledge base concerning green stormwater infrastructure and its applications at the local government scale. One goal of this research is to foster further communication between landscape architects

and other advocates of green stormwater infrastructure and decision makers in local governments in order to support efforts to address local- and watershed-scale problems related to urban stormwater runoff.

Chapter 2

Context and Background

This chapter explores the history of water-quality issues in the Delaware River Basin. Over the last four centuries, the Delaware River Basin has undergone numerous transformations. Before European settlement, the region was described as a pristine and beautiful landscape with abundant natural resources (Kauffman, 2010). After nearly 200 years of urbanization and industrialization in the watershed, the Delaware River had become as degraded as any river in the country. Since the 1940s, there has been a steadily growing political movement to restore water quality in the Delaware River, though, that has met with a relatively high level of success.

Eliminating point-source pollution has been the main priority for addressing water-quality since the 1970s. Fueled by regulations set forth by the Delaware River Basin Commission (DRBC) and the United States Environmental Protection Agency (EPA) in the latter half of the 20th century, water quality has improved significantly in the watershed. In the 21st century, however, stormwater runoff is now described as the main contributor to the degradation of water quality in urbanized watersheds (EPA, 2003). This chapter briefly describes the history of efforts to address water quality in the Delaware River Basin from the 1700s to present day.

This chapter also looks at traditional methods of managing stormwater at the municipal level and its hydrological impact on urbanized watersheds. Green stormwater infrastructure is introduced as an alternative to traditional gray infrastructure. As shown in Philadelphia and other cities across the United States, green stormwater infrastructure is an alternative that addresses several of the negative impacts of traditional gray infrastructure. Further, green stormwater infrastructure offers numerous additional environmental, social, and economic benefits to the municipalities that implement it as part of their urban construct.

The Delaware River Basin: General Characteristics

The Delaware River Basin stretches through southern New York, much of western New Jersey, eastern Pennsylvania, northeastern Delaware, and through just 8 square miles of northeast Maryland (see Figure 2-1). Classified as having a humid–temperate climate, the watershed has a mean annual precipitation measurement of between 39 and 47 inches. Geology, soil types, and topography vary throughout the Delaware River Basin. The Delaware River flows undammed for nearly 330 miles, and the watershed encompasses nearly 13,000 square miles of land (Ayers et al., 1994). Though the basin occupies only 0.4% of the land area of the continental United States, 5% of the nation's population depends on the Delaware River Basin as its primary water supply (Kauffman, 2011).

Between 2000 and 2010, the watershed's population increased by nearly 475,000 people such that by 2010 the area had a population of 8.2 million. To put this figure in context, if the basin were a state in the United States, it would be the 10th smallest in terms of land area, but the 12th largest in terms of population (U.S. Bureau of the Census, 2010a, 2010b). In addition to these 8.2 million residents, 8 million people in New York City and northern New Jersey also use the basin as their primary potable water supply (Kauffman, 2011).

Given the large number of people the Delaware River Basin serves, water is one of the most important natural resources (if not the most important) in the area. As of 2001, roughly 15% of the watershed's entire land area was urban (with a much higher percentage along the north and south gradient toward the Delaware Bay) and the urban population has continued to grow in the 21st century (Kauffman, 2011). The demand for useable water from the watershed is likely to rise in the future, and the continued growth of the urban environment may threaten the security of this resource unless sustainable approaches are taken in order to conserve clean, potable water.

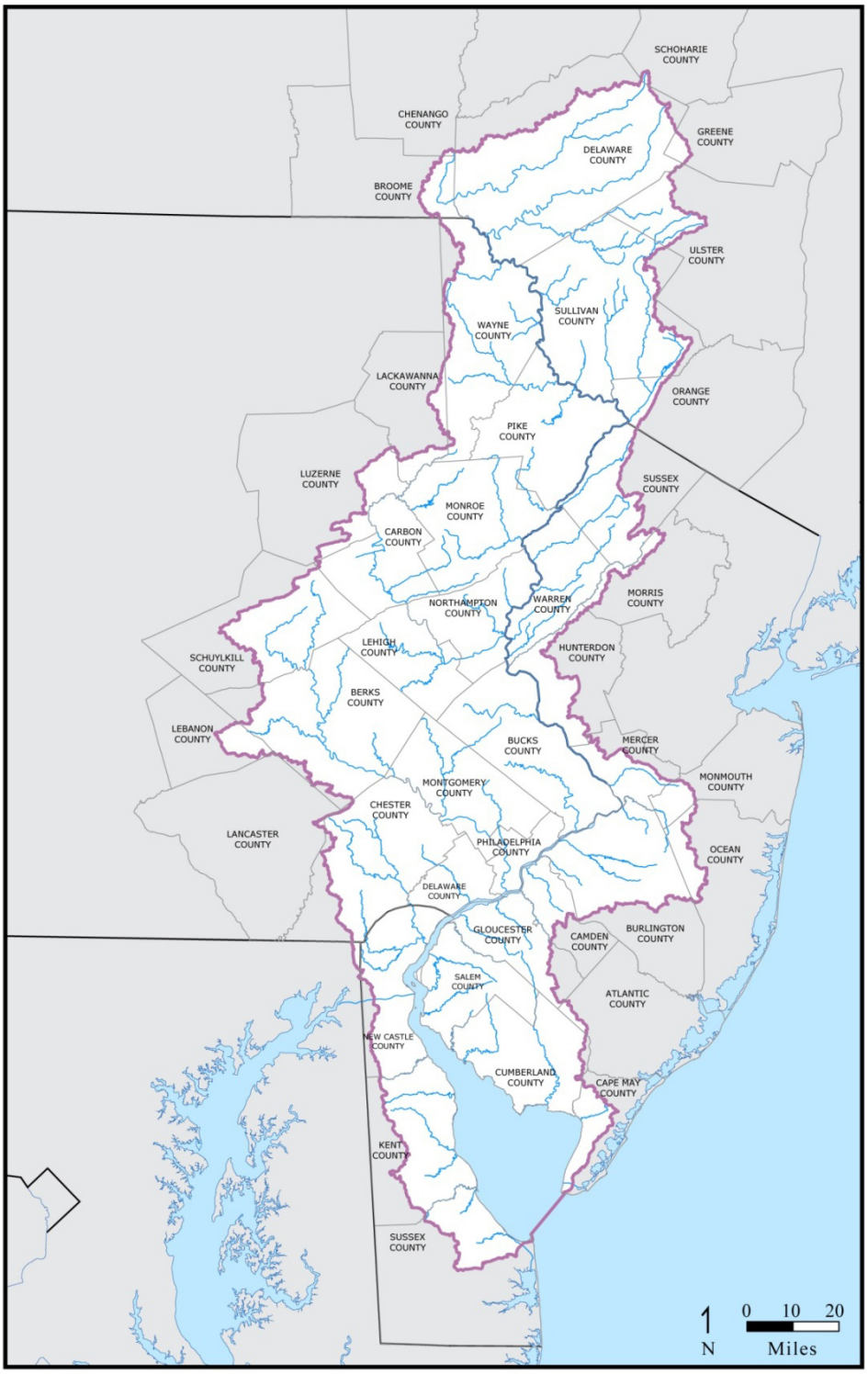

Figure 2.1: Delaware River Basin with Counties. Data is available through Pennsylvania Spatial Data Analysis; Delaware River Basin Commission data source.

Early Issues Related to Water Quality and the Political Response

Water pollution of the Delaware River Basin (1700s–1940s)

Written accounts of water pollution in the Delaware River Basin were published as early as 1739. Benjamin Franklin petitioned against the point source pollution from slaughterhouses and tanneries near Philadelphia that had been implicated in a noticeable spike in fish kills (Kauffman, 2010). Early efforts to remove these pollution sources, however, were largely ignored (Albert, 1988). Franklin continued to be concerned with water pollution near Philadelphia in the Delaware and Schuylkill Rivers into the late 18th century. He headed a committee focused on regulating water pollution in Philadelphia (McMahon, 1992), and even left money in his will for the specific purpose of developing a municipal water system for the City of Philadelphia (Philadelphia Water Department, 1987).

Conducted in 1799, the first pollution survey of the Philadelphia harbor area revealed numerous pollution sources—including shipping vessels and their associated ports, human waste discharge, and a number of early industrial sources (Albert, 1984). In 1800, Philadelphia and the Southwark district (part of present-day Philadelphia) had a combined population of over 50,000 people (U.S. Census Bureau, 1998) and were trumped only by New York City in terms of urbanized area.

Driven by the Industrial Revolution, the amount of pollution-rich waste being dumped into the Delaware River Basin continued to increase during the 19th century. Cholera, typhoid, and other water-borne diseases broke out in urban areas from the 1830s into the 1890s, killing thousands of people in the watershed (Kauffman, 2010). By 1860, several municipalities along the Delaware River, including Philadelphia, Camden, and Trenton had responded by creating upstream water supply intakes. Around the same time, the first rudimentary sewer systems were

created to prevent groundwater contamination in local wells. Hardly sophisticated in regard to structure, these sewer systems were sometimes built so simply that they comprised only “crude log pipes discharging to the nearest stream” (Albert, 1988, p. 101). By 1885, every town and city in the Delaware River area had established a municipal sewage system (Kauffman, 2010).

The makeshift efforts to alleviate public health concerns could not keep pace with the increasing urbanization of the Philadelphia metropolitan area. Between 1890 and 1915, nearly every municipality along the Delaware River abandoned the river as an untreated water supply. Some municipalities, including Philadelphia, built large filtration plants to serve as their public water source. Other cities, like Camden, drilled hundreds of wells and stopped using the Delaware River as a water supply source altogether (Albert, 1987). Either way, the poor water quality in the Delaware River Basin was not addressed. It was simply ignored. Public health concerns were alleviated, but the pollution in the Delaware River Basin continued to worsen well into the mid-20th century.

Political Action to Restore Water Quality (1930s–1970s)

The Interstate Commission on the Delaware River Basin (1939–1963)

It was not until 1939 that Delaware, New Jersey, New York, and Pennsylvania banded together to form the Interstate Commission on the Delaware River Basin (INCODEL) as “the first serious watershed movement to clean up pollution” (Kauffman, 2010, p. 441). The commission’s primary goal was to bring sewage treatment to towns and cities in the watershed to eliminate the dumping of raw sewage into the Delaware River. Additional goals included addressing conservation issues and water supply needs (Delaware Public Archives, 2009). Progressive in its

intent, the INCODEL would face numerous obstacles, such that many of its goals went unfulfilled—at least during the wartime period.

As Kauffman (2010) noted, war-time industrial demands were prioritized over eliminating point-source pollution. During World War II, industrial waste continued to pollute the river. Trenton was the only major city to implement a sewage treatment plant before the commission was shelved because of the demands made on industry by the war (Kauffman, 2010). By the 1950s, the Delaware River was "a dead river, as dead as any in the United States" and "the urban reach of the Delaware River was noted as one of most polluted stretches of river in the world" (Kauffman 2010, pp. 447–448). Revitalized after World War II, the INCODEL forced major cities and several smaller municipalities to install sewage treatment plants. And, as a result, the percentage of sewage discharges subjected to treatment increased from 20 to 75%, though other point-source pollution persisted (Albert, 1988). The river remained severely polluted well into the 1960s; in part because it was also burdened by low flow caused by drought and increased demands on the water supply from New York City, which took a percentage of its water from the headwaters of the Delaware River (Kauffman, 2010).

As one of the very first commissions of its kind, the INCODEL even found it difficult to establish appropriate regulations (Barry, 1970), and its role was essentially advisory in nature (Albert, 1988). Another issue, as Hines (1967) pointed out, was the INCODEL's lack of power: "Interstate agencies, like INCODEL … usually perform data gathering, educational and advisory functions, but, uniformly, they lack regulatory powers" (p. 436). The water-quality standards set by the INCODEL were enforced by the Board of Health of each state in the Basin (Delaware Public Archives, 2009). Without regulatory powers of its own, the INCODEL was hard put to ensure that standards were met, and forcing polluters to abide by defined standards was, in some cases, impossible (Barry, 1970). The INCODEL was disbanded in 1963, but it had certainly succeeded in encouraging change along the Delaware River. In fact, one of its most significant

achievements was that it had laid the framework for the future watershed regulatory commission, the Delaware River Basin Commission.

Early Federal Government Response (1948–1972)

Nearly a decade after the formation of the INCODEL, the United States government responded to growing concerns related to water quality in the urbanized watersheds. The Water Pollution Control Act of 1948 was the first major federal regulatory effort made in the United States to address water quality. Its primary goal was “to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters” (Fish and Wildlife Service, 2009). Furthermore, “During the development of such plans, due regard was to be given to improvements necessary to conserve waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural and industrial uses” (Fish and Wildlife Service, 2009). The act was amended numerous times leading up to 1972, and though the intentions behind it were good, it had several significant shortcomings.

As Barry (1970) pointed out and discussed in depth, the problems with early federal regulations were plentiful. Early obstacles included (1) an unrealistic division of power between federal and state government, (2) a lack of cohesion with other pollution laws, (3) the ability to easily bypass laws if the cost of abatement was economically or physically unfeasible as determined by the court, (4) a lack of incentive for polluters to discontinue before possibly appearing in court where they may or may not be ordered to comply, (5) failure to effectively gather data on pollution and polluters, (6) poor methods for determining appropriate water-quality standards themselves, and (7) a lack of enforcement power, because the laws were inherently not self-regulating.

Much like the standards set by the INCODEL, early federal regulations were not strongly enforced. The federal government expected state governments to bring a heavier hand to prescribing more stringent water pollution control. The federal government, in return, supported state governments in their efforts, but took little initiative on their own (Esty, 1996). The development of coherent and effective national rulings on water-quality issues was a slow process, and leading up to the 1970s, there was much to be desired in regard to setting and achieving higher water-quality standards (Barry, 1970).

The Delaware River Basin Commission (1961–Present)

To ensure the protection of the Delaware River and its tributaries, the Delaware River Basin Commission (DRBC) was formed in 1961 as the first federal–state watershed compact in U.S. history. When it disbanded in 1963, the INCODEL passed its remaining funds and resources on to the DRBC. Like the INCODEL, Pennsylvania, New Jersey, New York, and Delaware were collectively given responsibility for cleaning up point-source water pollution and addressing flooding throughout the Delaware River Basin (Cech, 2010). Unlike the INCODEL, however, the DRBC became a joint effort of the federal government and the governments of the four states within the watershed (DRBC, 2012).

The primary goal of the DRBC, upon its foundation, was to restore the Delaware River and its tributaries to swimmable and fishable water. In 1968, the DRBC imposed water pollution regulations that were more rigorous than any other federal or local regulations designed to address water-quality issues at the time (Kauffman, 2010). Furthermore, unlike the commissions that had come before, the DRBC had the “regulatory authority in all facets of water resource management” within the watershed’s boundaries (Albert, 1988).

Standards pertaining to dissolved oxygen levels and bacteria concentration became more rigorous in the 1960s. Toward the end of the decade, the DRBC allocated funds to 90 municipalities and industrial polluters for the purpose of upgrading wastewater treatment management (Albert, 1988). In line with these more rigorous standards, pollution stemming from point-sources has decreased dramatically since the 1970s. Fish populations increased and migration patterns began to recover (Albert, 1988; Kauffman, 2010). DRBC standards were subsequently used as minimum state standards for Delaware, New Jersey, New York, and Delaware (Albert, 1988). The Commission continues to deal with "water quality protection, water supply allocation, regulatory review (permitting), water conservation initiatives, watershed planning, drought management, flood loss reduction, and recreation" in the Delaware River Basin today (DRBC, 2012).

The Federal Water Pollution Control Act (1972) and the Clean Water Act (1977)

The 1972 Federal Water Pollution Control Act drastically altered the federal approach to addressing water-quality issues throughout the country (Gaba, 1983). Somewhat parallel to the DRBC's shift in regulatory enforcement, 1972 marked a major migration in water-quality control from the state governments to the national government. As a result of this act, states were required to meet or exceed the water-quality standards set by the United States Environmental Protection Agency and have been required to do so ever since (Esty, 1996).

In 1972, water-quality standards were established by determining technology-based limitations, in addition to the establishment of the National Pollutant Discharge Elimination System (NPDES). The EPA required all industries to reduce water pollution by using the "best practicable technology," technology that the EPA itself would define. Additionally, the NPDES program required all point-source dischargers to obtain a permit as a way for the EPA to monitor

discharges. If discharges were found to exceed the guidelines set forth by the Federal Water Pollution Control Act, the EPA had the authority to impose fines on individual dischargers (Gaba, 1983).

The 1972 regulations essentially imposed minimum water-quality standards across the country. The 1977 Clean Water Act (CWA), however, went further by pushing more strongly toward desired water-quality standards at the national level. This included establishing anti-degradation regulations and designating water uses. Waterways that had not yet been directly impacted by pollution were, in many cases, protected from any future degradation accruing from source-pollution as such pollution was disallowed. Total Daily Maximum Loads (TMDL) became a primary measuring tool based on which the EPA determined whether source polluters were discharging pollutants that exceeded a water body's capacity. The EPA was given the authority to implement pollution-control programs for industrial and municipal dumping. Polluting or discharging into any waterway in the country was determined to be unlawful unless an NPDES permit had been obtained. And though the regulations did become more restrictive, the federal government sought to offset this by providing billions of dollars in funding for the construction of sewage treatment plants throughout the country (EPA, 2012a).

As a result, $1.5 billion in federal grant money was spent on upgrading wastewater treatment plants along the Delaware River during the 1980s in an effort to meet the DRBC and CWA point-source pollution regulations. Preventing further human waste and other sewage from entering the local waterways would be accomplished by sizing systems to account for recent and future population growth, which would ultimately burden aging sewer systems. Ultimately, this funding resulted in cleaner surface and drinking water throughout the basin and supported the funding already allocated by the DRBC (Kauffman et al., 2008).

Gray Stormwater Infrastructure

Goals

As seen in the Delaware River Basin, the primary motivator for manipulating water infrastructure was that of improving public health. In most cases, municipalities first focused on securing a reliable water supply for their residents. A second goal, which was mainly a result of political enforcement since the mid-20th century, was to treat raw sewage and to prevent point-source pollution from entering local waterways (Hough, 1995). These two objectives had a lasting impact on urban infrastructure in the form of complex underground piping systems reinforced by expanding road networks and a growing urban construct (Anderson, 1988).

Urban stormwater runoff is another input into this expanding gray infrastructure. For most of the 20th century, the engineering goal related to stormwater management was simple: direct runoff from city surfaces into catch basins and underground pipes as quickly as possible (Boller, 2004; Girling & Kellett, 2005; Roy et al., 2008). Once stormwater enters the system, "It is here that, perceptually, the problem stops and connections with larger environmental issues of watersheds are not made" (Hough, 1995, p. 36).

Techniques

Once stormwater enters drain inlets in the urban environment, there are two general systems that determine the treatment and destination for the urban runoff. Though stormwater management varies slightly in each individual urban municipality, for the purpose of this research, "gray stormwater infrastructure" is categorized according to two broad techniques: (1) combined sewer systems and (2) separate sewer systems. Municipalities incorporate one or both

of these techniques, or other methods of discharging stormwater runoff. Overall, though, the gray stormwater infrastructure systems generally fall into one or the other of these categories.

Combined sewer systems transport both wastewater and stormwater in the same underground network of pipes, and they are often found at the "center of most older large cities and unplanned ones everywhere" (Debo & Reese, 1995, p. 2). Originally, combined sewers discharged this untreated water downstream. Since the Clean Water Act, and earlier in some instances, this combined storm/wastewater flows into municipal wastewater treatment plants. There, it is treated in order to meet some acceptable set of standards established by state or federal agencies, and the treated water is discharged into local waterways. Overall, only 772 of the tens of thousands of municipalities in the country use combined sewer systems. As these systems aren't found anywhere other than at the center of large cities, however, they serve about $1/8^{th}$ of the nation's population (EPA, 2008).

A separate storm sewer system, as the name implies, maintains separate piping systems—one for stormwater and the other for wastewater. Compared to combined sewer systems, this is a relatively new paradigm in gray stormwater management. The implementation of separate stormwater systems corresponded with the post-war population boom of the mid-1900s and the growing body of knowledge about the negative impacts of untreated combined sewer effluents on water sources and human health. In a separate stormwater system, wastewater is treated at a municipal wastewater treatment plant. Treated wastewater, once it has reached an acceptable quality standard (established by state or federal agencies), is then discharged into local waterways. On the other hand, stormwater is discharged directly into local streams or other surface waters, sometimes as quickly as possible, though at other times only after it has sat for a period on the surface or in underground catch basins (Debo & Reese, 1995).

Impact

Gray stormwater infrastructure has achieved its initial goals. By the 1970s, urban environments were dry and clean (Debo & Reese, 1995), and the management of storm and wastewater, coupled with the securing of municipal surface water sources, has greatly improved human health in the immediate urban setting. These systems, however, have several unintended consequences for natural processes impacted by water. As Alberti (2009) stated, “changes in the hydrological cycle due to urban development have significant physical, chemical, and biological consequences for ecosystems” (p. 134). Gray stormwater infrastructure threatens local water bodies with untreated runoff, and urban environments greatly affect the quantity, quality, and flow of water far beyond municipal boundaries.

Since the mid-1970s, “stormwater runoff has been recognized as a nationally significant source of water pollution” (Girling, 2002, p. 100). Picked up from impervious and other treated surfaces, the pollutants include nutrients, bacteria, heavy metals, pesticides, sediment, and various forms of solid waste. Stormwater often increases stream water temperature and sediment transportation and also decreases the amount of dissolved oxygen available for aquatic life. When combined sewer systems cannot handle heavy storm events, they overflow and dump the storm and wastewater concoction directly into streams, resulting in immediate and lasting impacts on ecosystems and on the quality of the water downstream (Alberti, 2009; Booth et al., 2004; Hough 2004; Paul & Meyer, 2001; Roy et al., 2008).

Additionally, the use of gray stormwater infrastructure increases the demands on potable water. A lack of infiltration means that more water is necessary for landscape irrigation. Rainwater, which could otherwise be conserved, is rapidly sent down pipes. Potable water is also used for activities, like car washing, that do not require drinking-standard water. These uses are exemplified in the urban environment (Alberti, 2009; Hough, 2004).

The urban landscape with its massive expanses of impervious surfaces impacts the flow regimes of local tributaries. Runoff is concentrated in pipes and discharged rapidly, which causes downstream flooding and also limits the time frame for infiltration. As Hough (2004) stated, in the urban environment, “rainfall is accompanied by extremes of flood and low flow” (32). These rapid discharges erode stream banks, destroy habitat areas, and burden ecosystems and communities downstream (Alberti, 2009; Girling & Kellett, 2005; Hough, 2004; Spirn, 1984).

Addressing Urban Runoff: Political Responses and Green Stormwater Infrastructure

Water Quality Act (1987–Present)

Issues related to stormwater runoff began to capture public attention after the creation of the CWA. In 1987, the EPA amended the act in order to address storm water discharges and non-point source pollution. For example, municipalities with certain land-use designations and population sizes were required to obtain NPDES permits for combined sewer overflows and for separate stormwater discharges (EPA, 2012C). Municipal stormwater discharge regulations were established in two phases.

In 1990, Phase I targeted large cities across the country and required combined sewer overflows and stormwater discharges to meet requirements set for point-source pollution. In 1999, Phase II required municipalities in urbanized areas with populations under 100,000 and with separate municipal storm sewer systems (classified as MS4 municipalities) to obtain NPDES permits for stormwater discharges and to meet minimum control measures (EPA, 2012A). Broad minimum control measures for MS4 include public education and participation, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control, and pollution prevention fact sheets (EPA, 2012c).

In the context of stormwater management, the EPA (2012b) encourages the use of green infrastructure as an alternative to gray infrastructure. Building on the amended CWA and the requirements for MS4 communities, the EPA defines green stormwater infrastructure as follows:

> [green infrastructure is] an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits and support sustainable communities. Unlike single-purpose gray stormwater infrastructure, which uses pipes to dispose of rainwater, green stormwater infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green stormwater infrastructure provides not only stormwater quality management, but also flood mitigation, air quality management, and much more.

Green Stormwater Infrastructure as an Approach to Stormwater Management

Goals, Techniques, and Impact

Through the use of natural systems and processes, green stormwater infrastructure effectively alleviates several of gray stormwater infrastructure's negative effects on urbanized watersheds. Three goals specific to stormwater management are (1) to reduce the demand on the potable water supply, (2) to raise water-quality standards, and (3) to stabilize flow regimes in urbanized watersheds. In helping to meet these goals, green stormwater infrastructure has also been shown to offer numerous social, economic, and environmental benefits to communities.

Common green stormwater infrastructure approaches to stormwater retention and filtration include using urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands, as well as other best management practices. Ultimately, these techniques "keep rainwater out of the sewer system which can lead to sewer overflows and also reduce the amount of untreated runoff discharged to surface waters by allowing stormwater to be absorbed and cleansed by soil and vegetation before flowing into groundwater or surface water resources" (CWAA, 2011). Thus, water quality is enhanced, flows are stabilized, and the demands on potable water curbed. The use of green stormwater infrastructure encourages infiltration, potentially combating flood events and also storing more water in the ground, which means that less potable water is used for landscape irrigation. Other environmental benefits include an increase in biodiversity and habitat areas, healthier and longer-lived vegetation, a reduction in air pollution, and relief from the urban heat island effect (Benedict & McMahon, 2002; Chocat et al., 2007; CWAA, 2011; OEC 2007). Financially, like gray stormwater infrastructure, green stormwater infrastructure requires only simple routine maintenance (CWAA, 2011), but the long-term cost of the latter is only a fraction of the cost incurred in overhauling an aging sewer system (Benedict & McMahon, 2002; Jaffe, 2010; PWD, 2011). Community residents also save on individual heating and cooling costs (Dunn, 2010; Gunderson et al., 2011). Property values increase along green streets and with close proximity to park systems and open space (Benedict & McMahon, 2002; CWAA, 2011). Physical health and psychological health are directly and positively impacted by the extent of the green space and recreational areas that green infrastructure offers (Benedict & McMahon, 2002; CWAA, 2011; Tzoulas et al., 2007). Additionally, urban noise pollution is reduced and green streets and spaces have been shown to foster positive community interaction (Dunn, 2010; OEC, 2007; Tzoulas et al., 2007).

Historical Uses of Green Stormwater Infrastructure

Designing green infrastructure systems to manage stormwater is not a new concept. In 1867, Frederick Law Olmsted and Charles Eliot designed the Boston Park System, which linked together five major Boston Parks by focusing green corridors around coastal rivers (Fábos, 2004). Olmsted's initial vision of the park system was based on reconstructing the natural quality and function of the tidal rivers, which had sustained the negative impact of human waste and pollution for decades (Spirn, 1986). Eliot later expanded the Boston Park System in an effort to preserve large areas of open space and wetlands and to improve connections between, and he did so with the overall aim of focusing on the water management of the larger Boston metropolitan area (Fábos, 1985). Early examples of green infrastructure developed to handle hydrologic issues had a range of supplementary purposes, including connecting fragmented urban and natural habitats, creating wildlife and native plant communities, managing open space for various human activities, and improving the overall image of communities (Walmsley, 1995).

Communities in the northwestern United States are often praised for their efforts to use green stormwater infrastructure on a large scale. In the 1970s, the suburban city of Bellevue, Washington, was under financial pressure, and citizens joined together to devise an open surface stormwater scheme to "handle urban stormwater" and "expand public greenways" (Girling & Helphand, 1997, p. 303). The system focused on expanding natural areas and parks, but it also improved the linkages from homes to "schools, libraries, recreational areas, historic and cultural resources" (Girling & Helphand, 1997, p. 311). The system was designed to protect riparian corridors, natural vegetation, habitat areas, and also to provide the citizens of Bellevue with, "natural scenic values, passive recreation, environmental education, and alternate transportation" (Girling & Kellett, 2005, p. 125). Bellevue is considered by some to be a model community in

regard to taking a comprehensive approach to using green stormwater infrastructure (Poole, 2000).

In the latter half of the 20th century, landscape planners and architects further explored the role of water in the developed environment with an eye to protecting watershed health. Hough (1984) called for a better understanding of how natural cycles, especially the hydrologic cycle, are impacted by the urban environment and by impervious surfaces in particular. Spirn (1984) also looked at how traditional methods of piping urban water to local waterways affect the environment. These two researchers agreed on the need to reassess stormwater practices on a variety of scales. They agreed likewise that green infrastructure approaches to stormwater management would minimize the effects of the urban environment and, therefore, should be considered the way forward. Additionally, the idea arose that stormwater management practices should not be restricted to just controlling water quality and quantity, but could also make "the water cycle visible and tangible to urban residents" (Girling & Kellett, 2005, p. 123).

Portland, Oregon, is perhaps the most well-known American urban center to adopt green stormwater infrastructure practices throughout the city. Portland's stormwater strategy is "committed to partnership-based, cost-effective, green approaches to healthy neighborhoods and water quality." The stormwater program encourages innovative "non-structural pollution reduction techniques like native landscaping, stormwater pollution reduction bioswales and ponds, and public involvement and education" (Hottenroth et al., 1999, p. 633). Portland's stormwater approach is an environmentally, socially, and economically sustainable solution that "[treats] the cause of the problem, not the symptoms" (Grewe et al., 2002, p. 8).

Green Stormwater Infrastructure in the Delaware River Basin

Despite the reduction in point-source pollution, thanks to the efforts of the DRBC and the environmental agencies of the represented states, urban runoff continues to negatively impact the Delaware River and its tributaries (Kauffman, 2010; Madden, 2010; PWD, 2011). Since the late 20th century, Philadelphia has been the subject of considerable criticism because of its gray infrastructure. The city's aging combined sewer overflow system would flood with urban runoff after as little as one-tenth of an inch of rain, and it would subsequently dump raw sewage and stormwater pollutants into the Schuylkill and Delaware Rivers (Bauers, 2009).

Following the 1987 amendments to the Clean Water Act, the EPA repeatedly fined Philadelphia for its failure to subject the city's water to any secondary treatment. Philadelphia needed to upgrade its water infrastructure in order to meet current standards. By 1990, federal grant money was no longer available for the purpose of upgrading wastewater treatment plants, and Philadelphia had to resort to state and federal loans in order to overhaul its infrastructure and avoid further fines from the EPA (Madden, 2010). The city's stormwater and wastewater system had become a financial burden. In 1997, the Philadelphia Water Department (PWD) formed a long-term control plan that expressed the need to address the combined-sewer overflows, water source protection, and urban runoff in a cost-efficient way. The PWD worked closely with the EPA, the DRBC, the Pennsylvania Department of Environmental Protection, and the Pennsylvania Environmental Council to explore the feasibility of using green infrastructure as a progressive and cost-effective approach to managing stormwater in Philadelphia.

The PWD and other local organizations with a stake in addressing Philadelphia's environmental concerns have embraced green stormwater infrastructure in recent years (Madden, 2010; PWD, 2011). Local media have become increasingly tuned in to Philadelphia's water crisis, and by the 2007 mayoral race, addressing environmental concerns had become an overarching

political objective and concern for Philadelphians (Bauers, 2009). Around the same time, universities and schools within the city began implementing green stormwater infrastructure techniques with promising results (Madden, 2010). In 2009, PWD published its newly funded "Green City, Clean Waters" plan centered around green stormwater infrastructure. The amended version includes this pledge: "commitments made in this plan will lay the foundation for a sustainable Philadelphia by greening our neighborhoods, restoring our waterfronts, improving our outdoor recreation spaces, and enhancing our quality of life" (PWD, 2011, p. 4).

Chapter 3

Problem Statement and Significance

Stormwater runoff is currently viewed as one of the key threats to water quality and one of the central causes of unstable flows in the Delaware River Basin. Green stormwater infrastructure has been shown to combat several of the negative impacts caused by the built environment. Philadelphia is the watershed's largest urban center in the watershed and, in recent years, the city has been at the forefront of the green stormwater infrastructure movement. Though Philadelphia's new approach to managing urban runoff will certainly reduce the negative effects of non-point source pollution within the Delaware River Basin, the city comprises only a fraction of the total drainage area and population of the entire watershed (U.S. Census Bureau, 2010b). Unlike Philadelphia, hundreds of other municipalities in the Delaware River Basin have not been subject to financial and political pressure in regard to upgrading their water infrastructure. Collectively, these municipalities contribute the majority of urban runoff to the Delaware River and its tributaries.

How are these other municipalities managing stormwater runoff? Have other municipalities within the Delaware River Basin embraced, considered, or rejected green stormwater infrastructure? Do municipal workers in leadership roles related to stormwater infrastructure view green stormwater infrastructure as a viable option for the future management of urban stormwater runoff? Philadelphia's efforts have been acknowledged on the national level; however, the work of other municipalities is not well-documented. Answering these questions by contacting individual communities in the watershed is an important initial step for assessing the current and future state of sustainable urban stormwater management in the Delaware River Basin. Additionally, understanding the values and issues related to municipal infrastructure and

the municipal employees' opinions of green stormwater infrastructure is essential to fostering communication between landscape architects, other advocates of green stormwater infrastructure, and decision makers in local government. Furthermore, by focusing on perceived drivers of and barriers to the implementation of green stormwater infrastructure may allow readers to think more critically about how to approach clients in regard to pursuing opportunities for green stormwater infrastructure. As thousands of small- and medium-sized municipalities surround the great cities of the United States, they have traditionally been implicated in water degradation. If efforts are not made to effectively communicate the values and benefits of green stormwater infrastructure to these communities, it is likely that the urban environment will continue to threaten the potable water and ecosystems that depend on its stability into the foreseeable future.

Chapter 4

Methods

Municipality Selection

There are 868 cities, towns, townships, boroughs, and other municipalities in the Delaware River Basin (DRBC, 2011); therefore, it was necessary to narrow the scope of this study to a manageable number of municipalities. The process of determining the municipalities to include in this research took place in two different phases.

The Delaware River Basin Commission provided an initial list of 23 municipalities defined as local population centers in the watershed with regional or larger-scale name recognition (Tessieri, 2011). The provided list was not generated with particular attention on stormwater management; instead, it included municipalities with other characteristics likely to benefit this study. One benefit of this approach was that the municipalities represented the entire region of the Delaware River Basin. Each of the four states within the Delaware River Basin had at least four municipalities on the initial list provided by the DRBC. A second benefit of the list was that it revolved around local population centers, such that the municipalities were likely to be urbanized and so required an established stormwater infrastructure.

However, too few municipal employees made commitments to participate in the study; therefore, the process of selecting municipalities entered a second phase designed to expand the initial list of 23 municipalities. In this second phase, the list of targeted municipalities was expanded to 41 and the researcher chose additional communities by identifying adjacent communities to the non-respondents from the initial list of 23 municipalities. All the

municipalities included in the study were situated along the Delaware River, in the Delaware Bay, or by one of the tributaries within the watershed.

Additionally, it was necessary for each municipality included in the study to have a government-maintained stormwater infrastructure system. In many cases, the responsibility for this system fell to the public works department or to a specific branch of that department. Municipalities that did not have either an urban environment that required a centralized stormwater management system and/or a governing body responsible for stormwater management were excluded from the study. In order to determine whether a specific municipality met this requirement, the researcher contacted municipal clerks and/or considered relevant information published on the websites of the local government bodies.

Participant Selection

The researcher selected municipal employees in each of the specified municipalities to participate in the study. In order to participate, each employee was required (1) to have strong knowledge of the community's stormwater infrastructure and (2) to be a leader of a municipal department.

A strong knowledge of a municipality's stormwater infrastructure is necessary for providing an accurate description of stormwater management techniques. Managers and others in leadership positions were also targeted because they were expected to have significant insights into the future of stormwater infrastructure in their communities. Additionally, such professionals are likely to be experienced in and knowledgeable about the social aspects relating to stormwater management in their respective communities.

For nearly every municipality, the individuals identified were directors of public works departments or other professionals directly identified by the directors themselves. These

alternates were managers of storm/wastewater branches within public works departments, with the exception of one professional, who was a municipal engineer.

Interview Process and Structure

Five open-ended questions were used to guide the interviews, which were conducted by telephone. The participants were assured that their answers would be confidential, and they were asked if they would allow their responses to be recorded for eventual transcription. Each of the 12 participants agreed to allow recording on the interviews. The interviews were recorded using the Livescribe Pulse Smartpen, which allowed simultaneous recording and note-taking digitally synced with one another. The recorded interviews were then uploaded, assigned a numerical code, and stored. Listed below are the five open-ended questions used to guide the interviews:

1. How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

2. Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands. If yes, what techniques have been used?

3. To your knowledge, has there been <additional> discussion of utilizing green infrastructure to manage stormwater among municipal board members?

4. What barriers do you believe may prevent or hinder the <further> inclusion of green stormwater infrastructure in your community?

5. Who, in your opinion, are the decision-making individuals most informed of the community values related to stormwater issues in your municipality?

Data Analysis Methods

The data gathered from this research were analyzed through conventional qualitative analysis, a method "generally used with a study design whose aim is to describe a phenomenon" (Hsieh & Shannon, 2005, p. 1279). In this research project, the phenomenon can generally be described as the acceptance of and transition to using green stormwater infrastructure for local governments within the Delaware River Basin.

Are municipalities using or have they begun a transition toward establishing green stormwater infrastructure? Are there plans to make this transition? What has hindered or motivated the use of green stormwater infrastructure in these municipalities? The interview structure was characterized by defined questions; however, the use of a qualitative analysis approach allowed the gathered information to be analyzed in a way whereby findings could accrue that were not targeted in the interviews. Additionally, the opinions of the participants were cross-referenced in order to reveal any commonalities and/or contradictions in opinions concerning green stormwater infrastructure.

The first step in the data analysis process was to become immersed in the data. This involved transcribing the interviews (see the Appendix) and reviewing the data as a collective body of literature (Tesch, 1990). Each recorded interview was played back repeatedly and transcribed manually, such that each constituted an individual Microsoft Word document. Each interview transcript was assigned a number, from 1 to 12, and each participant was henceforth referred to as "Participant n" with "n" being the number corresponding to the transcription file. The researcher reviewed each transcript several times in order to achieve two goals: (1) to ensure the accuracy of the transcripts (Poland, 1995) and (2) to begin identifying commonalities among the interview responses (Sandelowski, 1995).

The next step in the analysis process was to open code the data. The 12 individual transcripts were imported into the qualitative analysis software ATLAS.ti, which allows for coding across multiple primary documents (in this case, the 12 transcribed interviews). In accord with established research protocols, the initial coding identified reiterated words, attitudes, and concepts. The primary goal of the initial round of coding was to capture everything the participants described during the interview process (Miles & Huberman, 1994). The list of initial codes (or domains), which was extensive, was established based on multiple readings of all the interviews.

The third step in the data analysis process consisted of organizing the previously defined domains into categories. These categories often referred to as "clusters" (Hsieh & Shannon, 2005, p. 1279; Straus, 1987, p. 31) in qualitative analysis, consisted of related and linked domains (Patton, 2002; Sandelowski, 1995). In accord with established practices, any domains that were unrelated to other clusters and/or that had not provided rich information were manually omitted at this point in the analysis process, as there was insufficient data to effectively analyze (Basit, 2003). Much like the initial coding process, this was a tedious step requiring multiple readings of interviews and defined codes in order to determine which codes to combine and which to omit.

This study began with 72 domains defined through the initial coding process. The list of domains was subjected to a process of consolidation, which resulted in four major categories and 12 total domains as follows:

Green Stormwater Infrastructure: Understanding and Use

1. Understanding (Green) Stormwater Infrastructure
2. Green Infrastructure in Use and In Plan

Is Green Stormwater Infrastructure Desired?

3. Is Stormwater Infrastructure an Issue?
4. Attitudes toward Stormwater Management: Gray is Good Enough

5. Attitudes toward Stormwater Management: Gray Infrastructure is Not Good Enough

Physical Constraints to Implementing Green Stormwater Infrastructure

6. Scale
7. Available Space for Green Stormwater Infrastructure
8. Property Ownership
9. Soil Constraints

Financial Constraints and Opportunities for Green Stormwater Infrastructure

10. Perceived Costs of Green Stormwater Infrastructure
11. Availability of Funding for Green Stormwater Infrastructure
12. Who should pay for Green Stormwater Infrastructure?

The fourth step in the data analysis process was to address the clustered domains through the participants' words and the researcher's interpretation of them. This effort was central to the researcher's qualitative data analysis approach. A description of these domains is given in Chapter 6: Data Analysis.

The fifth step in conventional qualitative data analysis is to compare the findings in Chapter 6 to those presented in the existing literature on closely related topics. Parallels, discrepancies, and suggestions for further research are given for each of the domains. A discussion of how these domains relate to the existing literature is presented in Chapter 7. The final step in the data analysis process was to consider the results obtained in the research, and the research findings are discussed, opportunities and barriers are identified, and suggestions for further research are addressed in Chapter 8.

Chapter 5

Municipal Characteristics

Participant Response Rates

Over a three-month data collection period, employees from 12 municipalities in the Delaware River Watershed participated in this study. In total, 41 municipalities were interviewed during the data collection period via telephone calls conducted three to four times a week during normal business hours. Notes were left with the employees who answered the phones and up to three voice mails were left for each of the targeted employees who could not be reached directly.

The most obvious hindrance to the study was the lack of availability of many of the municipal employees targeted. In addition to being unavailable because of their usual responsibilities, public works directors (and those in similar municipal positions) were undoubtedly even more difficult to contact because the Delaware River Basin was subject to flooding during the summer of 2011. Hurricane Irene caused major flood damage in the watershed in the period of 27–30 August (see http://nj.usgs.gov/hazards/flood/flood1108/); therefore, preparation and consequential cleanup and/or infrastructure repairs consumed the time of a number of the employees targeted for this research. The employees who answered the phone to the interviewer frequently referenced the flooding as the main reason for the specified individuals' unavailability for participation.

Most of the non-participating employees simply did not return messages, whether the interviewer left them on voicemail, asked other members of staff to relay them, or sent them by email. Two of the 29 non-participating municipalities were unique in terms of why targeted

employees did not participate in the study. A staff member at one municipality stated that the department did not participate in interviews or surveys, even when confidentiality was assured. A second potential participant failed to be available for an interview at the agreed date and time, and subsequent calls to this person were not returned.

Characteristics of Participating Municipalities

Municipality	State	Munic. Type	Major Tributary	Distance Upstream from Bay
1	Delaware	City	Mispillion River	10 miles
2	Delaware	City	Delaware River	20 miles
3	New Jersey	City	Delaware River	80 miles
4	New Jersey	City	Delaware River	100 miles
5	New York	City	Delaware River	220 miles
6	Delaware	Town	Broadkill River	10 miles
7	Delaware	City	White Clay Creek	20 miles
8	Pennsylvania	City	Schuylkill River	120 miles
9	Pennsylvania	City	Schuylkill River	160 miles
10	Pennsylvania	City	Lehigh River	150 miles
11	New Jersey	Borough	Mantua Creek	60 miles
12	New Jersey	City	Salem River	10 miles

Figure 5.1: Characteristics of Participating Municipalities. State, Municipal Type, Major Tributary, and Distance Upstream from the Delaware Bay.

State and Municipal Type

At least one municipality from each of the four states in the watershed participated in this study. New Jersey and Delaware each had four participants from municipalities in their respective states. Three participants were employees of municipalities in Pennsylvania, and one was an employee in from New York. Ten municipalities with participants in the study were cities, another was a town, and another a borough. Though municipal types can be considered indicators of population density or land cover, the characteristics of different municipality types vary greatly

from state to state. For inclusion in the study, each municipality had to maintain a central stormwater infrastructure system. This was the only inclusion criterion beyond location in the Basin, such that municipal type had no bearing on whether a municipality was considered for this study.

Major Tributaries and Distance Upstream from Delaware Bay

The major tributary of each municipality was determined by using the geospatial analysis software ArcMap10. Data were accessed through the Delaware River Basin Commission, which included major streams and rivers. If more than one tributary ran through or near a municipality's boundaries, the tributary defined was determined by the closest measured distance downstream to either the Delaware River or the Delaware Bay.

The distance upstream from the Delaware Bay was also determined using the geospatial analysis software ArcMap10 to measure the distance from the mouth of the Delaware River to each specific municipality. Municipal boundary data were accessed through the Delaware River Basin Commission. The distance was measured along the tributaries as measured from the geospatially defined mouth of the Delaware River (39°25′13″N 75°31′11″W) to the closest boundary of each municipality. For municipalities located below the mouth of the Delaware River (i.e., municipalities that discharged stormwater directly into the Delaware Bay), the distance was measured from the mouth of the respective tributary, along the tributary, to the nearest municipal boundary. The figures were rounded to ten as a way to ensure that information pertaining to the municipalities and participants remained confidential.

		Population (2010)	Pop. Density (#/sq.mile)	% Pop. Change (00-10)	Med. Household Income	NPDES MS4 Regulations
Municipality	1	9,500	1,000	42.0%	$45,000	No
	2	71,000	6,500	-2.5%	$38,000	Yes: Phase II
	3	85,000	11,100	-0.6%	$37,000	Yes: Phase II
	4	4,000	3,400	1.0%	$72,000	No
	5	9,000	3,500	-0.4%	$43,000	No
	6	2,500	1,400	55.5%	$41,000	No
	7	31,500	3,400	10.2%	$53,000	Yes: Phase II
	8	88,000	8,900	8.5%	$28,000	Yes: Phase II
	9	14,000	3,400	-7.9%	$32,000	Yes: Phase II
	10	118,000	6,700	10.7%	$36,000	Yes: Phase I
	11	18,500	2,000	-2.5%	$55,000	Yes: Phase II
	12	5,000	2,200	-12.9%	$26,000	No

Figure 5.2: Characteristics of Participating Municipalities: 2010 Population, Population Density, Percent Population Change 2000–2010, Estimated Median Household Income, and National Pollutant Discharge Elimination System MS4 Regulation Requirements.

Population Characteristics, Trends, and NPDES Regulations

Figures in regard to the 2010 population, population density, percent population growth, and 2010 median household income data were provided by the U.S. Census Bureau (2010c, 2010d, 2010e, 2010f, respectively). For confidentiality, the 2010 population was rounded to the nearest five hundred, population density was rounded to the nearest hundred, and median household income was rounded to the nearest thousand. The National Pollutant Discharge Elimination System MS4 regulation requirements were provided by the EPA (2007) "Urbanized Area" website. Minimum control measures for these MS4 communities included public education/outreach and participation/involvement, illicit discharge detection and elimination, construction-site runoff control, post-construction runoff control, and pollution prevention/good housing fact sheets (EPA 2012b). Specific details of the minimum control measures are available on the EPA's website: Stormwater Discharges From Municipal Separate Storm Sewer Systems (MS4s).

Chapter 6

Data Analysis

Green Stormwater Infrastructure: Understanding and Use

The first subchapter within the data analysis chapter focuses on the current status and understanding of green stormwater infrastructure in 12 municipalities within the Delaware River Basin. Two domains are addressed in this first subchapter. The first domain refers to how well-understood the concept of green stormwater infrastructure is in individual communities. This level of understanding is discussed in terms of municipality residents, municipal decision makers, and the interviewed individuals. If individuals are well educated in regard to green infrastructure, they may become more interested in utilizing alternatives to gray stormwater infrastructure.

The second domain discussed herein is the current use of green stormwater infrastructure techniques within the selected municipalities. The techniques used cannot be summarized as a collective approach for the entire watershed; however, this study provides a small sample that may yield useful information about what other municipalities within the watershed are doing concerning green stormwater infrastructure. Understanding what the sample group has done provides a context for a further analysis of attitudes toward green stormwater infrastructure.

Understanding (Green) Stormwater Infrastructure

The municipal employees who were interviewed for this research were directors of public works offices, or they were employees in a similar capacity to whom the researcher was referred after requesting to talk to a stormwater specialist. It was assumed, then, that the participants

would be well informed about the infrastructure used for stormwater management in their municipalities. And, this proved to be the case; however, knowledge of and interest in green stormwater infrastructure varied considerably among the participants. Through the interview process, it became clear that overall the participants can a general understanding of what constitutes green stormwater infrastructure. Additionally, several participants talked about the level of understanding of other members of their communities in regard to green stormwater infrastructure, and more generally, in regard to stormwater management. This domain explores these perceptions.

As a note, unlike other subjects in the data analysis, this domain focuses on each individual municipal participant initially (as opposed to focusing on specific topics). Afterward, generalized assessments were made in regard to the entire group of municipalities.

Participant 1 discussed differences between community stakeholders in regard to sustainable methods for stormwater management whereby one group of government stakeholders was clearly interested in restoring the water quality of the local tributaries. Another participant appeared to represent a larger train of thought expressing skepticism about or lacing a complete understanding of the benefits of green stormwater infrastructure.

> Municipal Participant 1:
> *Last year, we did put together a committee of sorts to help develop standards that the community could live with to limit total loading on the [local] river.*
>
> *… they wanted to put in pervious pavement along the building in the fire lane and not have any traffic there. But the Fire Marshall said no, they didn't trust it.*
>
> *I don't think people are necessarily opposed to it, maybe they are just used to the way things have been done.*

Participant 2 discussed the administration's support for moving toward what he called, "green solutions." The participant understood that reducing the amount of direct stormwater runoff entering local tributaries was important and that it was an aim of green infrastructure. Yet, he questioned whether other citizens had a similar understanding of green stormwater infrastructure, despite an effort to increase green stormwater infrastructure through financial incentives.

Municipal Participant 2:
We have done some, what are known now as green solutions… they're all part of what we like to call the "tool box of ideas" but you have to look at the opportunities.

The benefit would be the greatest reduction in runoff entering the local water body.

… there are incentives in place, but are those incentives alone enough to drive people toward doing green things with their property is an open question.

Unlike the first two municipal participants, the participant 3 questioned his own understanding of where green stormwater infrastructure may be appropriate and of the benefits that might result from using it. Additionally, the participant doubted that citizens of the municipality had a strong knowledge of the more environmentally sensitive approaches to stormwater management. Though he applauded the political leader of the municipality for attempting to educate the city's youth on the topic of green solutions, overall the participant felt that the effort was ineffective.

Municipal Participant 3:
I don't know how well this question actually pertains to us. It is an urban area.

Hell, I feel like I don't know what many of the benefits are.

When we talk about these urban areas … a lot of times we're talking about poverty-stricken people who are not educated. So, from my experience, the higher in class and education you go, the more earth-friendly people become for some reason. I guess they're more knowledgeable so they try to do the right things.

I don't think our administration is anti-green, our mayor is very park conscious. He's trying to spread that kind message, especially to the younger children.

But in a lot of ways, you're trying to get blood from a stone.

Participant 4 discussed the general lack of understanding of what stormwater management on the part of people in the community. The participant did not fully elaborate on his own understanding of green stormwater infrastructure, but he did acknowledge green stormwater infrastructure as a goal for decision makers in the local government.

Municipal Participant 4:
Really, not a lot of people know about the stormwater management. You say stormwater management to some people and they may look at you and not have any idea what you're talking about.

We mainly push to go that way, anyway.

Similarly, participant 5 did not specifically address his own understanding of green stormwater infrastructure. In fact, this participant expressed very little interest in the topic. The participant stated that there was "no need" for green stormwater infrastructure in the community; therefore, it is likely that the participant did not understand or appreciate green stormwater infrastructure and the benefits that can accrue from it.

Municipal Participant 5:

I certainly wouldn't say that we are opposed to those types [green] of management techniques, especially for future development, but there is really no need for it right now.

The sixth participant acknowledged the positive impact that green stormwater infrastructure could have on water-quality and -quantity issues. Yet, outside of "taking care of streams," the participant did not elaborate on other known impacts that green stormwater infrastructure can have on stormwater runoff.

Municipal Participant 6:

Some of the green stuff is good, but some of it I think goes overboard. Taking care of streams, you know I think is good but sometimes people get carried away with it all.

Participant 7 discussed how green stormwater infrastructure fit into the municipality and expressed a clear understanding of the subject. His concern was the existence of a disconnect between members of the community and stormwater management. Moreover, he felt that the local government did not understand the education level of residents in regard to stormwater management.

Municipal Participant 7:

I would say most people do not care about stormwater management unless their basements get flooded out. They just don't realize the importance of it.

I don't think anyone has a feel for stormwater, or how the community feels about stormwater management.

For participant 8, understanding green stormwater infrastructure was a learning experience. The participants expressed an appreciation for green stormwater infrastructure in their

community. Conversely, he suggested that the lack of knowledge about green stormwater infrastructure may be tied to a resistance-to-change attitude evinced by other members of the community.

> Municipal Participant 8:
> *Back ten years ago, Hurricane Allison came through the area and blew out a dam at [the local] lake. It blew out the dam, and of course our thoughts at the time were that we had to rebuild the dam. We actually went through getting a professional design done, and we went through the bidding process. The bids were much higher than the cost estimates were. So at that time, we decided to look into what else could be done.*
>
> *… any time in this area you try something new, people rebel and say "Well, that's not the way we always did it." We'll certainly get some of that reaction.*

Participant 9 did not discuss his own understanding of green stormwater infrastructure. On the other hand, he did note that stormwater was something that residents did not want to be bothered with. The participant's comments suggest that the residents do not have a clear understanding of stormwater management, or at the very least, that they do not want to spend time thinking about it.

> Municipal Participant 9:
> *Homeowners don't want to spend extra money to treat the stormwater. They just want us to take care of it.*

Similar to participant 8, participant 10 indicated that he was in a learning process in regard to green stormwater infrastructure. Participant 10 mentioned different green stormwater infrastructure techniques (including green roofs) and discussed his personal knowledge on the subject, but also his efforts to learn more about them.

Municipal Participant 10:

Yes, we recently went to see a green roof that was installed several years ago near the city. The purpose for the visit, why we wanted to go see that, is I am looking at city-owned buildings that would perhaps be good candidates to install green roofs on. From both a water-quality perspective and for the energy efficiency, I'm trying to help insulate the buildings for heat and cooling.

Participant 11 discussed his knowledge of stormwater-quantity issues as a learning experience, though he came by his knowledge by chance. As a problem presented itself (in this case, substantial flooding), it became necessary for him to understand issues related to stormwater. On a personal level, however, the participant seemed to believe that the municipal planning board should have the deepest understanding of green stormwater infrastructure among municipal employees.

Municipal Participant 11:

As far as everything else goes, we're always looking toward ways to improve water flow, you know especially after these last couple storms. It's opened our eyes, we've never really had this kind of water before. There are some things that we need to work on, you know, like stream management and stuff like that.

As far as if you're asking me if we're going green … the old stuff is obviously not. Anything new, I'm sure the planning board is looking at it.

Participant 12 did not go into depth concerning his understanding of green stormwater infrastructure. Though he suggested that another municipal employee may understand more of the technicalities associated with the stormwater system, he also pointed out that her connection to the social implications might also be limited.

Municipal Participant 12:

... you could contact the municipal engineer, but I'm not sure she'd be that tuned into the community values aspect of it. But she would certainly know more of the technicalities.

In summary, each municipality and its community members' knowledge of green stormwater infrastructure was unique. Some participants displayed a fairly proficient understanding of the issues at hand. Others did not reference their own understanding of the topic, and still others admitted that they simply did not know much about green stormwater infrastructure. Moreover, the participants were not asked to elaborate on their knowledge of green stormwater infrastructure, but rather to talk about how green infrastructure fit into their community's plans for managing stormwater runoff. It is impossible to decipher each participant's knowledge level of knowledge in regard to the topic at hand, no municipal participant described himself/herself as an expert on green stormwater infrastructure. Even the participants who established their understanding of green stormwater infrastructure noted that they were in the process of learning about it.

Several participants discussed a disconnect between community residents and issues pertaining to stormwater management. According to their comments, without the support or drive to move toward green stormwater infrastructure on the part of community members, empowering the local government to make changes to the stormwater infrastructure is likely to be difficult. When residents have little understanding of the issues related to stormwater, they have no incentive to take action.

As discussed by some of the participants, however, a lack of residential support is not necessarily the factor most responsible for preventing the further exploration of green stormwater infrastructure within individual communities. In some cases, other municipal employees and decision makers were resistant to change. Such resistance may, or may not, have been related to a

lack of understanding of the different aspects of green stormwater infrastructure. Overall, with a greater understanding of the subject, community members on all levels may further appreciate green stormwater infrastructure and its potential benefits.

Green Stormwater Infrastructure in Use and in Plan

In the interview process, the participants were asked to discuss green stormwater infrastructure within their communities. The participants were initially asked if their municipalities used any green stormwater infrastructure. If they responded "yes" to this question, they were asked to elaborate on the specific projects or methods used. Examples of specific techniques of green stormwater infrastructure were offered to participants as a starting point for discussion. The question was posed as follows:

> Interviewer:
> *Does the municipality you work for utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.*

The interviews with the participants who stated that their municipalities did use green stormwater infrastructure showed that a variety of techniques were in use across the 12 municipalities. Many of the techniques coincided with the examples provided by the researcher. However, the participants also described other techniques as being in use in support of green stormwater infrastructure.

Urban forests and tree plantings were discussed by two of the participants. One participant suggested that his municipality's urban forestry program was having a direct impact on alleviating stormwater issues.

Municipal Participant 2:
We also have an urban forestry program, and one of the objectives there is to increase the tree canopy, and that really ties into the whole stormwater mission.

The same municipal worker recognized that improving stormwater issues along existing municipal roadways would entail constructing tree beds and consequential tree plantings.

Municipal Participant 2:
We haven't done any green infrastructure along roadways yet, although that is a strategy that we might pursue as time goes on. That would involve construction of tree beds and things like that and some combination of that and porous paving or some kind of storage mechanism that runs water into the tree beds.

Participant 3 discussed citywide tree plantings as an example of green infrastructure in use. However, this participant did not make a distinct connection between urban tree plantings and stormwater management. Instead, he discussed tree plantings as an example of something green that may not be directly related to stormwater infrastructure.

Municipal Participant 3:
I mean, we aren't totally void of going green... The city has actually invested in a lot of tree plantings, citywide… We have planted thousands and thousands of trees over the last ten years or so. But other than that, there is nothing that really comes to mind…

Pervious pavement was another technique frequently referenced by the participants. And, at least two of the municipalities had installed porous pavement on a small scale.

Municipal Participant 2:
We've done some porous pavements on parking lots at a small scale.

Municipal Participant 4:
There is one little development that has permeable concrete.

Two other participants discussed pervious pavement as a viable option for future projects and for retrofitting existing pavement. In both examples, the participants looked at pervious pavement as a positive alternative to traditional pavement and the associated stormwater runoff.

Municipal Participant 11:
One of the things that they're trying to do is this concrete where the water will go right through it. So porous concrete, where the water will go through it, rather than digging basins and stuff like that. So the porous concrete has layers underneath it so the water can be dispersed into the streams at a different rate than having regular concrete, where it'd wash into a basin and then slowly gets washed in.

Municipal Participant 10:
Also looking at where we've rebuilt streets to add porous pavement. A main reason why we're looking at that is because there are definitely areas in the city where we could do it, but there are certainly areas where we cannot do it because of the geology. But I think there are areas where we can do it, significant areas.

A fifth municipality had planned for permeable pavement along a building owned by the local government, but the plans were rejected. The participant cited the city fire marshal's lack of trust in the alternative technology as implicated in the decision to forego pervious pavement in favor of impervious pavement.

Municipal Participant 1:
There have been some plans submitted through private management for pervious pavement and so forth, but they have been rejected by the city—in one case, the Fire Marshall. That was for a building, they wanted to put in pervious pavement along the building in the fire lane and not have any traffic there.

Whereas several participants referenced permeable paving strategies, only two participants discussed rainwater harvesting in terms of collecting water in cisterns or rain barrels for reuse. In practice, only one municipality had installed cisterns (albeit on a small scale), whereas another municipality had explored options for using rain barrels on private property. The second participant seemed enthusiastic about rainwater harvesting, although all efforts in this regard were still in the planning process.

> Municipal Participant 2:
> *Cisterns, not that many; there have maybe been a cistern or two installed on one of the properties that we've worked on but not that many. We've actually done work on a library where we actually do have a cistern and sort of a rain-barrel-type arrangement; it's a large system.*

> Municipal Participant 9:
> *We've been dealing with the County Conservation District and have presented some information to home owners about doing rain gardens and some things like that, like rain barrels. There has been an effort to incorporate things like that, but nothing is in place right now.*

Similarly, the use of green roofs was fairly limited in the focus group of municipalities. Two participants pointed to a limited use of green roofs, although neither elaborated on whether this approach had shown an effect on stormwater management. A third participant, on the other hand, seemed fairly interested in further exploring the opportunity for various environmental reasons.

> Municipal Participant 2:
> *We've done green roofs, to a small extent.*

> Municipal Participant 3:

We even have an apartment complex that has a green roof downtown.

Municipal Participant 10:
From both a water-quality perspective and for the energy efficiency, I'm trying to help insulate the buildings for heat and cooling. We don't have any concrete plans in place yet, but I am in an investigation process to look to put green roofs on. I would like to put them on our city hall and public safety building. They have big roofs.

Rain gardens, or bio-retention systems, were in use in multiple municipalities. On public land, one municipality had implemented rain gardens at local education facilities. A second municipality was planning to use bio-retention along existing roadways.

Municipal Participant 6:
Well, we've been testing some rain gardens at the library and at the school which the stormwater enters before it goes to the river. They're fairly small. Those are relatively new.

Municipal Participant 10:
… we're looking at is doing some bio-retention along the streets. We have a project that we're working on right now, but we have limited funding on it, so I don't know if we'll be able to get it included into this project. I would like to include some bio-retention areas along a roadway project that we're doing. It's an existing collector road.

The use of bio-retention facilities also extended to private property. Some homeowners had rain gardens in one municipality. In other municipalities, rain gardens were being used by private developers.

Municipal Participant 2:
We've done, basically on larger homes with enough garden area, we've done rain gardens.

Municipal Participant 10:
We're also in the process of updating our subdivision and land developing ordinances and putting in a requirement for bio-retention in new subdivisions.

Municipal Participant 7:
So in the past couple of years, we have approved quite a few bio-filtration facilities.

Bioswales, like the bio-retention systems, have been used in new developments by private developers. Unlike the bio-retention systems, however, there was no emphasis on implementing bioswales on public land or in existing development.

Municipal Participant 7:
We have used bioswales.

Municipal Participant 3:
We have some bioswales in new construction.

Municipal Participant 1:
There is one subdivision that has bioswales, but that's managed by the HOA and that's about it.

Municipal Participant 10:
We have a few bioswales. There is not a great deal of development in the city because we're fairly well built out. But there have been a few developments where we have required the bioswales to go in.

Municipal Participant 3:
We want all new construction that happens here, I can't remember exactly what it is based on, but we do require the bioswales, so that we can re-perk the soil.

Two participants discussed the use of constructed wetlands within their communities. Both municipalities represented by these two participants had completed public projects, but one of the municipal participants referenced a larger project done by a private client. In both cases, the participants noted that the wetlands helped to mitigate the effects of stormwater runoff.

> Municipal Participant 8:
> *We designed an environmental park. It has wetlands, meadows, and we redid all of the stream banks.… We have built about a two acre wetland area, and that does help with the stormwater.*

> Municipal Participant 12:
> *Yes, in the last couple of years we've been involved with constructing wetlands along the river.… They do help out with stormwater somewhat, but it is a private project. We have implemented some smaller wetland projects on our publicly owned land, but that was a larger project.*

It is worth noting that when the participants were asked to specifically address green stormwater infrastructure, they referenced two other stormwater management techniques. One participant talked about retrofitting drain inlets when asked to describe the use of green stormwater infrastructure.

> Municipal Participant 3:
> *… we actually retrofit our inlets so that they don't allow floatables from going into them. That's going a long way in preventing floatables and other materials from getting into the collection system and ending up in waterways.… You protect the environment…*

A second participant also referenced the use of detention basins in new developments when discussing green stormwater infrastructure.

Municipal Participant 4:

The big ones are the new developments. They have the detention basins.

	Municipality											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
***Use:* U.F. / Tree Plantings**		■	■									
***Use:* Pervious Pavement**		■		■								
***Use:* Rainwater Harvesting**		■										
***Use:* Green Roofs**		■	■									
***Use:* Rain Gardens**		■				■	■			■		
***Use:* Bioswales**	■		■				■			■		
***Use:* Constructed Wetlands**								■				■
***P.P.:* Pervious Pavement**	■									■	■	
***P.P.:* Rainwater Harvesting**									■			
***P.P.:* Green Roofs**										■		
***P.P.:* Rain Gardens**										■		
***P.P.:* Bioswales**			■									

Figure 6.1: Green Infrastructure in Plan and in Use. Shaded areas are topics that municipal participants specifically discussed. U.F. = Urban Forests, P.P. = Planning Process.

In summary, 11 of the 12 municipal participants discussed the use or planned use of the aforementioned green stormwater infrastructure techniques (urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands) in their communities. Five of the 11 participants referenced only one of the previously mentioned green stormwater infrastructure techniques. Two participants discussed the use of two techniques in their communities. Only three of the 12 municipal participants noted that their communities were using or had planned for three or more green stormwater infrastructure techniques.

All but one municipal participant readily talked about green infrastructure as a means for managing stormwater in their communities, but the overall use of green stormwater infrastructure relayed by municipal participants was underwhelming.

Is Green Stormwater Infrastructure Desired?

The second subchapter moves beyond the level of understanding green stormwater infrastructure evinced by municipal participants and community members. Instead, this subchapter focuses on social variables associated with the potential future use of green stormwater infrastructure. Essentially, this subchapter explores this question: Is green stormwater infrastructure something a municipality wants?

The first domain focuses on whether municipal residents perceive stormwater as an issue that should be addressed by local governments. Understanding how issues relating to stormwater are understood by residents and by the participants is important in determining how local governments prioritize stormwater in comparison to other public issues.

The second domain looks at how gray stormwater infrastructure is currently perceived by municipal participants. This topic focuses on the extent to which municipal participants' conceptual goals for their stormwater management practices parallel government standards. This domain also looked at municipalities' work in upgrading or retrofitting their current stormwater management systems with additional gray infrastructure.

This second domain addresses opinions expressed by municipal representatives that current gray stormwater infrastructure may not be a desirable approach to managing stormwater runoff at the municipal level. This domain also explores municipal goals for green stormwater infrastructure as an alternative to gray infrastructure and future goals and community standards for green stormwater infrastructure.

Is Stormwater Infrastructure an Issue?

The importance of addressing issues related to stormwater management was not universal for communities within a region or even within a watershed. This domain looks at the importance of stormwater management to community members within the selected group of municipalities. The extent to which stormwater management issues were considered important may be directly related to the level of green stormwater infrastructure in the planning stages and in practice.

For some communities' residents, alleviating water-quality and -quantity concerns may not be a priority. Other services provided by the government, according to one participant, were more important in serving the population.

> Municipal Participant 3:
> *We're struggling to provide services for its constituents on a normal basis. To go above and beyond… there's a lot of aspects for making those types of changes. That's the situation here.*
>
> *You protect the environment, but you're causing additional work for the sewer utility and you're raising the ire of constituents that aren't getting what they feel they should be getting anyway, because of the economic situation. So it's tough.*

According to another participant, it was assumed that stormwater management was not a priority for community members. Neither was stormwater management a priority for the municipal office he represented. A second participant concluded that community residents did not want to be bothered with stormwater management.

> Municipal Participant 7:
> *We send out a survey every five years to poll the residents on our services, but stormwater is not included on that. I don't think anyone has a feel for stormwater, or how*

the community feels about stormwater management. We've got a substantial park system, so there is a high priority for having open space available to people, but that is not geared toward stormwater.

Municipal Participant 9:
Homeowners don't want to spend extra money to treat the stormwater. They just want us to take care of it.

On the other hand, one municipal participant suggested that residents care about stormwater issues only when they are directly affected by them.

Municipal Participant 7:
I would say most people do not care about stormwater management unless their basements get flooded out. They just don't realize the importance of it. People, they live along the creek right now, you know if we have a 100 year storm, some of them have problems with their basements and so forth. But if we didn't have so many of the stormwater facilities in the city, their properties and their houses could get flooded out completely. They just don't realize that. I'll tell you the people that live along the streams are more apt to care about stormwater but the people that live in the center of town that have to shell out money for the maintenance of their stormwater facility—if they didn't have to pay for it they wouldn't want to pay for it.

In one instance, water infrastructure became important to community members when an important piece of local culture was destroyed. Instead of replacing a piece of old infrastructure, the municipality used naturalized approaches that were also socially accepted.

Municipal Participant 8:
There was one interesting project for us. Back ten years ago, Hurricane Allison came through the area and blew out a dam at [the local] lake. It blew out the dam, and of course our thoughts at the time were that we had to rebuild the dam. We actually went

> *through getting a professional design done and we went through the bidding process. The bids were much higher than the cost estimates were. So at that time we decided to look into what else could be done. We decided not to replace the dam since really the only use of it was recreation. We decided not to replace it and kind of let nature take its course. We designed an environmental park. It has wetlands, meadows, and we redid all of the stream banks and let the stream go back to its original course from 150 years ago. That park is very, very successful.*

Not all the participants discussed the extent to which community members prioritized stormwater management issues. Some of those who did, though, noted that stormwater was just not important to residents. Similarly, it may be safe to assume that at least some of the participants did not talk about residents and their relationship with stormwater simply because it was not a pressing issue. When stormwater was a priority for community members, it was because they were directly impacted by it—physically or socially.

Attitudes toward Stormwater Management: Gray Infrastructure is Good Enough

As municipal participants discussed their current and future means for managing stormwater runoff, many reflected on the reasons governing the current stormwater strategies used in their municipalities. Several participants expressed satisfaction with their current stormwater infrastructure. Two main themes throughout the interviews support this attitude. One theme was that conceptual goals for stormwater management reflected requirements set forth by state and federal government. A second theme involved the physical goals for maintaining existing gray stormwater infrastructure.

State and federal standards were referenced by eight of the 12 municipal participants when discussing their stormwater management systems.

Municipal Participant 11:
Federal and state law, you know there are certain guidelines that need to be followed…

Municipal Participant 7:
Delaware regulations for stormwater cover both quantitative measures and qualitative measures. We basically reflect what the state requires of us.

Municipal Participant 2:
In light of new TMDL allocations and things like that, we have been working on limiting the amount of overflows that occurs so we can meet our total maximum daily load obligations in the area of streams.

Municipal Participant 4:
With stormwater regulations through the state, anyway we have to have a certain percentage of permeable areas according to your site plan.

Municipal Participant 10:
The city is under NPDES permits, because of the size of the city, we've been doing this for quite a few years now: we have an extensive stormwater system throughout the city and have a couple of discharge points. We actually take water samples and have them tested where they discharge into streams.

One participant seemed discouraged by government standards. The participant acknowledged certain requirements, but made it clear that meeting those requirements was not an easy task.

Municipal Participant 6:
The government mandates things and a lot of times you don't have money to do it or enforce it. That's the main thing. You know, they'll mandate rules and want you to do things but they don't give you any money to do it.

Municipal Participant 6:

… a lot of these issues are mandated by state or federal anyway, so we don't really have a choice.

In another instance, a municipal participant mentioned his municipality's exclusion from federal discharge standards.

Municipal Participant 1:
You know, we're a small city, under 10,000 so we don't need to meet NPDES regulations for our total maximum load or anything like that.

Through the interview process, it became clear that several municipalities looked at state and federal codes as the measuring stick for their methods of addressing stormwater management issues. Adhering to government standards was a goal, and when achieved, the participants seemed satisfied with their communities' stormwater infrastructure.

Municipal Participant 4:
As long as we're up to the rules and government mandates, a lack of funding really prevents anything above and beyond that.

Municipal Participant 3:
We meet all state standards for stormwater management. Are we perfect? No, but nobody is. When we're required to do something, we do it.

Municipal Participant 7:
… it is basically our priority the meet the state regulations.

Concurrent with meeting government regulations, another goal for several municipal participants was to maintain the current gray infrastructure within their communities. As (mostly) public works directors or employees, this was an essential part of their work.

Municipal Participant 11:
As far as our part, we maintain all of the basins that we have, we maintain all of the stormwater inlets—we clean them yearly.

Municipal Participant 1:
We deal a lot with the conservation district, so managing and maintaining what we have in place is a big part of it.

Municipal Participant 12:
But we're primarily focused on maintaining the existing system because we're a relatively small city and there isn't much new construction going on.

Municipal Participant 6:
Basically, we just maintain what system we have in, as far as stormwater runoff we have. It's been around for years.

Another aspect of maintaining gray stormwater infrastructure in the municipalities included upgrading the system using gray solutions or techno-fixes. Four municipal participants discussed gray infrastructure upgrades to supplement the existing stormwater system.

Municipal Participant 10:
Through the years we have been installing what we call a "snout." It is a cover that goes over the discharge pipe and inlets.

Municipal Participant 3:
Because of the stormwater management plan that we have in place, we actually retrofit our inlets so that they don't allow floatables from going into them. That's going a long way in preventing floatables and other materials from getting into the collection system and ending up in waterways.

Municipal Participant 2:

Over the last decade, we have engaged in a series of what are called in-pipe strategies for controlling overflows from that system.

Municipal Participant 8:
It is showing its age. There have been a few projects to supplement it, to replace parts of it…

In summary, several municipal participants hold rules and regulations set by state and federal government as the standard for stormwater management. To go beyond these requirements was not something that local governments were readily able to do. Furthermore, upgrading current systems could be accomplished by implementing new gray infrastructure practices. These changes clearly demand planning efforts and financial support.

Attitudes toward Stormwater Management: Gray Infrastructure is not Good Enough

As the previous domain considers the satisfaction of existing stormwater systems, this domain explores participants' statements regarding how gray stormwater infrastructure can be improved. Two themes support the idea that the participants considered green stormwater infrastructure as an improvement over existing gray stormwater infrastructure. The first and more prominent theme is the use of green stormwater infrastructure as a goal for new construction. The second theme is direct recognition that green stormwater infrastructure is the right thing to do.

As the participants were asked to discuss the use of green stormwater infrastructure within their respective municipalities, several discussed current or future plans involving new construction. The use of green stormwater infrastructure was seen as an ideal for some municipalities and a minimum requirement for others.

Municipal Participant 3:
We have some bioswales in new construction.

Municipal Participant 6:
Basically, anything new is leaning toward green infrastructure.

Though some participants stated that green stormwater infrastructure was a known solution, others expressed the hope that future plans would incorporate green solutions. The participants evinced a certain level of faith that green stormwater infrastructure would be the starting point of any new construction and carried through if possible.

Municipal Participant 5:
I certainly wouldn't say that we are opposed to those types of management techniques, especially for future development, but there is really no need for it right now.

Municipal Participant 11:
As far as if you're asking me if we're going green… the old stuff is obviously not. Anything new, I'm sure the planning board is looking at it.

Municipal Participant 4:
We mainly push to go that way, anyway.

In other instances, the municipalities required new construction to have green stormwater infrastructure. Requirements were often mandated by the local government, although state and/or federal law may have influenced these ordinances.

Municipal Participant 3:
We want all new construction that happens here, I can't remember exactly what it is based on, but we do require the bioswales, so that we can re-perk the soil.

Municipal Participant 4:
Well, there hasn't really been that much of a push for those types of management practices other than in new construction… but the city does require those types of things in any new development.

Municipal Participant 10:
There is not a great deal of development in the city because we're fairly well built out. But there have been a few developments where we have required the bioswales to go in.

Municipal Participant 4:
Our requirement right now is to change catch basin grates to say that no wastewater is going to streams. Anytime we have new construction, that's what we have to update to.

Municipal Participant 10:
We're also in the process of updating our subdivision and land developing ordinances and putting in a requirement for bio-retention in new subdivisions.

One participant suggested that green stormwater infrastructure was the right thing to do. This is important to point out, because although several participants acknowledged that green stormwater infrastructure may have considerable advantages as compared to gray stormwater infrastructure in regard to environmental sustainability, they did not express the opinion that green infrastructure should be put in place.

Municipal Participant 3:
When we talk about these urban areas… a lot of times we're talking about poverty-stricken people who are not educated. So, from my experience, the higher in class and education you go, the more earth-friendly people become for some reason. I guess they're more knowledgeable so they try to do the right things.

In summary, several municipalities had begun to encourage or require the implementation of green stormwater infrastructure in both new construction and new development. Yet, none of the participants mentioned establishing rules and regulations for using green techniques as a replacement for existing infrastructure. New stormwater infrastructure, in the context of these interviews, featured as a target for green stormwater infrastructure, whereas retrofitting existing stormwater infrastructure with green infrastructure received less attention. Despite the use of green techniques in new construction, existing infrastructure may fail to meet higher standards set for new construction, and thus the total negative impact of the municipality on urban water may not be significantly reduced.

	Municipality											
	1	2	3	4	5	6	7	8	9	10	11	12
S.W. - Not a Priority			■				■		■			
S.W. - Priority if Prominent Issue							■	■				
Gray is Good if Meeting Regulations	■	■	■	■		■	■			■	■	
Gray is Good - Maintain Existing	■					■					■	■
Gray is Good - Upgrade with Gray		■	■					■		■		
Gray not Good - Green New Constr.			■	■		■			■			
Gray not Good - Green is Future				■	■						■	
Gray not Good - Green is Better			■									

Figure 6.2: Is Green Stormwater Infrastructure Desired? Shaded areas are topics that municipal participants specifically discussed. S.W.= Stormwater; Constr. = Construction.

Physical Constraints to Implementing Green Stormwater Infrastructure

The third subchapter focuses on four main topics related to the physical manifestation of green stormwater infrastructure: scale, space, property, and soil. This subchapter focuses on whether participants perceived the physical characteristics of their communities as encouraging or hindering the transition to green stormwater infrastructure.

Green stormwater infrastructure has no prescribed scale. This differs dramatically from traditional gray stormwater infrastructure, which, in many cases, strives to account for all stormwater runoff within a delineated area. It is, therefore, important to explore the scale at which participants think green stormwater infrastructure can be implemented. Space, in this context, refers to what participants view as the space available or unavailable for using green stormwater infrastructure. Several participants viewed the available space as a key component in determining the feasibility of implementing green stormwater infrastructure within their communities. Property ownership is another variable that participants referred to when discussing green stormwater infrastructure. The disparity between public and private land and the perceptions of private landowners were also discussed. Finally, soil constraints were discussed by two of the participants as having an impact on whether it was possible to use green stormwater infrastructure techniques in their communities.

Although this subchapter focuses on physical constraints, it is important to point out that these are constraints defined by participants. Though the focal subject was physical constraints, several participants discussed the social values or norms influencing these constraints.

Scale

Several of the participants discussed the limited green stormwater infrastructure within their communities. Some acknowledged that the techniques implemented were limited or that the number of techniques available was underwhelming. Two participants, in particular, discussed the issue of scale as an impediment to the future inclusion of green stormwater infrastructure in their communities. Green stormwater infrastructure was viewed as a solution to stormwater-related issues on a small scale.

> Municipal Participant 2:
> *We have done some, what are known now as "green solutions"…but it's a much slower process because you're dealing with small scale.*
>
> Municipal Participant 3:
> *Some of the things… seem like they would happen on a small scale, and it would be hard to implement them on a large scale…*

Participant 2 (of a municipality that had a stronger commitment to green stormwater infrastructure than many of the others) continued by suggesting that because of issues of scale, green stormwater infrastructure may not be effective for dealing with stormwater at the municipal level.

> Municipal Participant 2:
> *… in the scheme of things they are all capturing water from relatively limited areas.*

None of the participants discussed green stormwater infrastructure as an all-encompassing alternative to traditional gray stormwater infrastructure, and it may that the issue of scale had strong impact on that train of thought because participants may fear of inefficiency. Traditional gray stormwater systems are predominantly designed to move all the stormwater runoff within a delineated drainage area. Yet at no point in the interview process did any of the participants clearly state exactly how significant an impact green stormwater infrastructure could have on these drainage areas or on stormwater management systems in general.

Each green stormwater infrastructure practice has a specific impact on stormwater management, similar to the specifications of sizing pipes, inlets, catch basins, or other components of gray stormwater infrastructure. When green stormwater infrastructure is deemed a small-scale approach, it may be caused by a lack of understanding technical variables associated

with green stormwater infrastructure techniques; whereas technicalities involved with gray stormwater infrastructure are “by the book”.

In many ways, designing a gray stormwater system to handle only a small percentage of urban runoff could also be considered a small-scale solution. Similarly, implementing enough green stormwater infrastructure practices to handle all urban runoff could be considered a large-scale solution. Green stormwater infrastructure may initially be a small-scale solution, but that stigma is more likely a reflection on the small number of techniques implemented, rather than on the effectiveness of additional, available techniques themselves.

Available Space for Green Stormwater Infrastructure

One physical barrier described by multiple participants included the limited space available for green stormwater infrastructure in their municipalities. Three participants noted that their municipalities were built out or otherwise lacked the space needed for new stormwater management practices.

> Municipal Participant 10:
> *There is not a great deal… because we’re fairly well built out.*

> Municipal Participant 7:
> *Yeah, [the municipality] is pretty much built out… So one of the limitations for using any kind of quality control, really, is space limitations.*

> Municipal Participant 9:
> *Right now there is a lack of space in a lot of the areas as it is urban…*

One participant described the major construction of green stormwater infrastructure in his community as a direct result of space becoming available, in this case, because of flood damage. Without this suddenly available space, it is unlikely that the described green stormwater infrastructure project would have come to fruition.

> Municipal Participant 8:
> *We decided not to replace the dam since really the only use of it was recreation. We decided not to replace it and kind of let nature take its course. We designed an environmental park... We have built about a two acre wetland area, and that does help with the stormwater.*

Some space had also become available in another municipality. The participant noted, however, that it had failed to meet the spatial demands of green stormwater infrastructure.

> Municipal Participant 7:
> *These sites are so small, and they don't have that much room to put these facilities on them.*

Lack of space, however, had not deterred all the municipalities from working toward green stormwater infrastructure. Several examples of green stormwater infrastructure that participants referenced had been implemented in areas of their municipalities where space was limited. Participant 2, for example, described how several green stormwater infrastructure techniques could work in the urban environment.

> Municipal Participant 2:
> *We've done some porous pavements on parking lots at a small scale. We've done, basically on larger homes with enough garden area, we've done rain gardens. We've done green roofs, to a small extent. Cisterns, not that many; there have maybe been a*

> *cistern or two installed on one of the properties that we've worked on but not that many. We've actually done work on a library where we actually do have a cistern and sort of a rain barrel type arrangement.… We haven't done any green infrastructure along roadways yet, although that is a strategy that we might pursue as time goes on. That would involve construction of tree beds and things like that and some combination of that and porous paving or some kind of storage mechanism that runs water into the tree beds. We also have an urban forestry program, and one of the objectives there is to increase the tree canopy, and that really ties into the whole stormwater mission.*

In summary, several participants viewed green stormwater infrastructure as requiring prescribed and considerable space for implementation. Other participants, however, described projects that had been implemented or planned in areas where space was limited. Opinions on available space varied greatly among the participants.

Overall, nearly all the participants considered the space available for the use of green infrastructure to be extremely limited. Space became readily available due to undesired consequences (specifically, the failure of existing infrastructure). Natural disasters, failed infrastructure, or urban vacancy all contribute to the availability of space for green infrastructure. Obviously, these catalysts are undesirable for local governments. Using green stormwater infrastructure, however, can offset several of the negative aspects associated with dilapidated land. Additionally, retrofitting existing infrastructure can help prevent older gray stormwater infrastructure from failing, either by reducing the volume of runoff entering an existing system or by phasing out existing infrastructure in a planned and controlled way.

Property Ownership

A third physical constraint discussed by municipal participants was the role of private property. This domain relates to the previously discussed topic of available space for green

stormwater infrastructure, but focuses on areas of a municipal government that do not relate to publicly owned lands.

Participant 2 implied that issues pertaining to green infrastructure in his community were complicated by dealing with multiple property owners. A second participant, participant 5, discussed barriers to the future implementation of green stormwater infrastructure within the community, first referring to a lack of public property. This participant made a distinction between private and public lands and their relative opportunities for green infrastructure.

> Municipal Participant 2:
> *When you deal with a smaller scale, you're dealing with many more players.*

> Municipal Participant 5:
> *There are two reasons. A restriction in available public property…*

The first of the aforementioned participants admitted both the importance and difficulty of engaging private land owners in regard to stormwater management.

> Municipal Participant 2:
> *Private property is a large component of runoff; it's really dealing with institutional issues of engaging with private property owners.*

The same participant, in addition to participant 9, discussed the limited success of local governments in regard to working with landowners on green stormwater infrastructure. One municipality had installed rain gardens, whereas another municipality was engaged in a planning process to provide services to homeowners.

> Municipal Participant 2:

We've done … on larger homes with enough garden area, we've done rain gardens.

Municipal Participant 9:
We've … presented some information to homeowners about doing rain gardens and some things like that, like rain barrels. There has been an effort to incorporate things like that, but nothing is in place right now.

One other municipal participant discussed the success of a private project. The construction of wetlands in this municipality, however, had been entirely independent of the local government.

Municipal Participant 12:
They do help out with stormwater somewhat, but it is a private project. We have implemented some smaller wetland projects on our publicly owned land, but that was a larger project.

Through the interview process, participants made a clear distinction between managing stormwater runoff on private property and managing stormwater on public property. In many of these municipalities, public land is extremely limited. Stormwater runoff, however, does not adhere to property boundaries, and municipal stormwater systems must account for all stormwater within a delineated topographic boundary. Engaging private landowners was done on a limited scale in two instances, but there was no evidence of a strong public to private approach to stormwater management on a larger scale for any of the municipalities. Efforts to engage private landowners in other municipalities may not have occurred or they may have been unsuccessful.

Soil Constraints

Another perceived physical constraint, though brought up less frequently, pertained to the soil conditions within specific municipalities. Two participants, in particular, described problems with infiltration techniques because of the municipality's geology. In one case, a participant described the soil as being too impenetrable for infiltration. The second participant discouraged infiltration in some areas of the municipality because he feared that such practices would pollute the city's water sources.

> Municipal Participant 7:
> *Infiltration practices, now, that's very hit or miss here in [the municipality] because we have very clayey soil in most cases. So, infiltration just doesn't exist.*

> Municipal Participant 10:
> *We are in a karst geology, so infiltration, depending on where we're at in the city, we're limited to use infiltration. We have about four different water sources, one of our water sources is <provides spring name> and that aquifer extends under our downtown area. So, we basically don't ask for or even like if they put infiltration in those areas.*

Of the two participants who discussed soil constraints, participant 10 described the city's karst geology as the major barrier to the further implementation of green stormwater infrastructure. Unlike other participants who focused on the expense involved in using infiltration techniques, these two participants emphasized problems in regard to infiltration as the major barrier to implementing green systems.

> Municipal Participant 10:
> *… the costs certainly come into play, but in my mind that is minimal compared to the infiltration of water into a karst geology.*

In both cases, however, the participants were somewhat optimistic that some areas in their municipalities did not have such geologic constraints. One participant described a testing process for desired infiltration availability, whereas the second participant noted that there were areas that may not necessarily threaten water supplies.

Municipal Participant 7:

We usually require, wherever a stormwater facility will be, we usually require a geo-tech to come in and do infiltration tests. If infiltration is possible, then we require infiltration.

Municipal Participant 10:

… are definitely areas in the city where we could do it, but there are certainly areas where we cannot do it because of the geology. But I think there are areas where we can do it, significant areas.

In summary, two of the 12 municipal participants discussed soil constraints as impacting the use of green stormwater infrastructure within their communities. The specific concerns were similar in the sense that they had to do with infiltration, but dissimilar in the sense that one according to one participant his municipality was struggling to achieve the desired infiltration, whereas another participant viewed infiltration as a threat to the quality of the public water supply.

Another interesting point was that the discussion of soil constraints was limited to only two municipalities. None of the participants expressed any major or minor concerns in regard to the current soil conditions in their respective municipalities. The two participants who did discuss soil constraints, however, showed a deeper understanding of how green stormwater infrastructure fit into their specific municipality, relative to other participants. Understanding the connection

between soils and infiltration in the conversation of stormwater management alludes to a certain exploration and interest in using a more sustainable stormwater infrastructure.

	Municipality											
	1	2	3	4	5	6	7	8	9	10	11	12
Green S.W.I. - Small-Scale Solution		■	■									
L.O.S. hinders Green S.W.I.							■		■	■		
Green S.W.I. when Space Available								■				
L.O.S. doesn't hinder Green S.W.I.		■										
Private Prop. hinders Green S.W.I.		■			■							
Private Prop. success Green S.W.I.		■							■			■
Soil type hinders Green S.W.I.							■			■		

Figure 6.3: Physical Constraints for Green Stormwater Infrastructure. Shaded areas are topics that the municipal participants specifically discussed. S.W.I .= Stormwater Infrastructure, L.O.S. = Lack of Space, and Prop. = Property

Financial Constraints and Opportunities for Green Stormwater Infrastructure

Of all the barriers to implementing green stormwater infrastructure mentioned by the municipal participants, limited financial resources was the one referenced most often. Financial concerns fell into three major categories: perceived costs, available funding, and the question of who should be responsible for the construction costs in individual communities. These concerns are addressed in this, the fourth subchapter of the data analysis.

The first domain explores how participants view green stormwater infrastructure compared to traditional gray stormwater infrastructure in terms of upfront and long-term costs. The perceived cost has a definite impact on whether green stormwater infrastructure is seen as a viable approach for local governments. A second domain focuses on funding for green stormwater infrastructure. Several municipal participants indicated the belief that a lack of funding constitutes a hindrance to the use of green stormwater infrastructure techniques. It is apparent that municipalities would welcome state and federal funding, and the availability and

accessibility is explored. Beyond these two domains, a third looks closely at whom participants believe should be responsible for providing green stormwater infrastructure, and the discussion shows that in several cases, participants felt that the responsibility for this ought to fall to other government stakeholders.

Perceived Costs of Green Stormwater Infrastructure

Several participants referenced high upfront costs associated with the implementation and construction of green stormwater infrastructure. Some of the participants implied that the main reason green stormwater infrastructure had been limited or non-existent in their municipal stormwater systems was the high upfront costs. Similarly, other municipal participants saw high costs as a barrier to or at least the major reason for delaying the use of green stormwater infrastructure in the community. For some, expense was the main barrier, and for others it was at least an obstacle in the planning process.

> Municipal Participant 12:
> *The only thing that really comes to mind is the cost.*
>
> Municipal Participant 3:
> *There is very little of that here only because there are costs associated with all of that...*
>
> Municipal Participant 10
> *Other than that, the costs certainly come into play, but in my mind that is minimal…*

Participant 11 noted that the costs incurred in implementing green stormwater infrastructure techniques were sometimes higher than those incurred in implementing traditional gray stormwater infrastructure.

Municipal Participant 11

Well I think probably the cost. You know, none of this stuff is cheap. You know porous concrete is probably two to three times the cost. Anything new coming out, I'm sure at first, will be more expensive.

For other participants, there was no distinction made between the implementation of green stormwater infrastructure and gray stormwater infrastructure. Upgrading current stormwater infrastructure was something worth pursuing for some participants, but the costs associated with making any improvements (whether they are green or gray) to their existing system were the principal deterrent to doing so.

Municipal Participant 8:

There have been a few projects to supplement it, to replace parts of it; but there just isn't that much money around for projects of that magnitude. As you can imagine, it is very expensive.

Municipal Participant 5:

… the other, and more important reason, is the financial end of it. I certainly wouldn't say that we are opposed to those types of management techniques, especially for future development, but there is really no need for it right now.

Participant 3 acknowledged an argument that long-term savings could accrue from putting green stormwater infrastructure in place. However, the initial investment was perceived as too costly by the participant, such that a system of this nature had not been installed.

Municipal Participant 3:

… a lot of people would argue that you're saving money down the road, but there's a lot of aspects for making those types of changes. If you need the money upfront to make those types of changes, you just don't have that type of money.

In one instance, a participant discussed a project in which replacing existing gray stormwater infrastructure was more expensive than focusing on more sustainable approaches. The participant was surprised at the cost of replacing the existing infrastructure. According to the participant, the project in question, though not particularly geared toward stormwater management, had many standing environmental and social benefits.

> Municipal Participant 8:
> *Back ten years ago, Hurricane Allison came through the area and blew out a dam at [the local] lake. It blew out the dam, and of course our thoughts at the time were that we had to rebuild the dam. We actually went through getting a professional design done, and we went through the bidding process. The bids were much higher than the cost estimates were. So at that time we decided to look into what else could be done. We decided not to replace the dam since really the only use of it was recreation. We decided not to replace it and kind of let nature take its course. We designed an environmental park. It has wetlands, meadows, and we redid all of the stream banks and let the stream go back to its original course from 150 years ago. That park is very, very successful. We have all kinds of natural habitats there now, and it's worked well. We have built about a two acre wetland area, and that does help with the stormwater.*

Though many municipal participants perceived green stormwater infrastructure as an expensive investment, in most cases there was no clear evidence that municipalities had fully explored other options. In only a few instances did participants discuss the monetary costs of green techniques in comparison with the costs of traditional gray stormwater infrastructure. The majority of the participants assumed that any improvements to their current stormwater systems would entail considerable costs and thus not be made. Green stormwater infrastructure was only assumed to be more expensive than traditional gray stormwater infrastructure. Though the cost of doing any project, as opposed to leaving a system as-is, demands an initial investment, the extent

to which each municipality investigated the potential economic benefits of implementing green stormwater infrastructure or whether in fact they did so at all remained unclear.

The long-term economic benefits of green stormwater infrastructure were discussed by two of the participants. One participant noted potential savings in terms of maintenance costs, but the upfront investment outweighed the long-term reduction in expenses. Another participant was surprised to find that the upfront cost of replacing gray stormwater infrastructure outweighed the cost of using a more environmentally friendly approach. Despite some initial skepticism associated with cost, the participant was proud to discuss the additional environmental and social benefits that green stormwater infrastructure had provided.

Availability of Funding for Green Stormwater Infrastructure

Beyond the perceived costs of green stormwater infrastructure, several participants who were interested in using green stormwater infrastructure acknowledged that a lack of funding had forestalled implementation. Some participants expressed the view that putting green stormwater infrastructure in place was not possible because no funding was available to support such an effort.

> Municipal Participant 6:
> *Money. That's number one—money. That's the primary force on anything in any small town: money. The government mandates things, and a lot of times you don't have money to do it or enforce it. That's the main thing.*

> Municipal Participant 4:
> *As long as we're up to the rules and government mandates, a lack of funding really prevents anything above and beyond that.*

Municipal Participant 3:
… we're not funded for that type of thing, it is that simple.

Municipal Participant 6:
Sometimes, you just don't have the money to do it.

Many participants expressed the belief that if the local government had available funds, they would pursue green techniques, or at a minimum, upgrade their current systems.

Municipal Participant 10:
Another thing, in addition to the green roofs that we're looking at is doing some bio-retention along the streets. We have a project that we're working on right now, but we have limited funding on it, so I don't know if we'll be able to get it included into this project.

Municipal Participant 8:
It is showing its age. There have been a few projects to supplement it, to replace parts of it; but there just isn't that much money around for projects of that magnitude.

Municipal Participant 3:
It basically boils down to economics, if we had the money, I'm sure we'd do some of it.

Municipal Participant 1:
Also, there isn't a lot of money coming in, so doing those types of things can be difficult.

In one scenario, a participant expressed the opinion that homeowners did not want to spend money on stormwater management such that funding through local taxes would be unpopular.

Municipal Participant 9:

Right now there is a lack of space in a lot of the areas as it is urban, and then also the cost. Homeowners don't want to spend extra money to treat the stormwater. They just want us to take care of it.

On the other hand, in two separate municipalities, funding was provided by state and federal government for the purpose of improving water quality. In one municipality, projects included separating a combined sewer overflow system and planting street trees citywide. A second participant described a private wetland construction project that was funded by the state's Department of Environmental Protection.

Municipal Participant 3:
There was a time in this city where a good portion of the collection was combined, that would be about 30–35 years ago. With some federal and state grants that the city received, they separated a lot of it. We're down to less than 5% combined sewer here.

Municipal Participant 3:
The city has actually invested in a lot of tree plantings, citywide. It's a lot of federal and state money, but they have done that. We have planted thousands and thousands of trees over the last ten years or so.

Municipal Participant 12:
The DEP had allocated over 20 million to the county last year to restore wetlands throughout the county, and a small portion of that money has been used within the municipality. Now, I should be clear that this is not something we've directly been doing, but there is one large industrial company in town that received some funding. I believe they actually brought in a professional landscape architecture consultant to design some wetlands along the river. They do help out with stormwater somewhat, but it is a private project.

In summary, several municipal participants discussed a lack of available funding as a major barrier to using green stormwater infrastructure. Only two participants discussed federal or state funding that contributed to the use of green stormwater infrastructure in their municipalities. None of the participants discussed the process of requesting funding for public projects associated with stormwater management, including the two participants who were aware that funding had been received previously.

Money was a perceived sticking point for many of the participants. It can be determined from the interviews that several municipalities did not have access to any funding for the purpose of changing their current stormwater-runoff management systems. It was not possible, however, to determine whether the municipalities had explored possible funding sources or the extent to which they had done so. A lack of available funding may be a stated problem in municipalities, and it can be expected to be a problems.

Who Should Pay for Green Stormwater Infrastructure?

A third domain related to the cost of green stormwater infrastructure is the question of who should be responsible for paying for it. Outside of state and federal funding, some municipal participants believed that other stakeholders in their communities, i.e., private-property owners and developers. should contribute to the funding of green stormwater infrastructure.

Two municipal participants described stormwater utilities either in use or in the planning stages in their communities. These utilities act as an award system for private-property owners. If private-property owners reduce runoff from their land or implement green stormwater infrastructure techniques, they can take advantage of tax breaks or some other form of credit.

Municipal Participant 2:

We do have a stormwater utility, which we've introduced three years ago. We do charge people on a basis of their footprint, their discharge runoff footprint and as a consequence of that program, there is incentive for property owners to try to reduce their footprint because we give them a credit. We have a credit program for that. So there are incentives in place, but are those incentives alone enough to drive people toward doing green things with their property is an open question.

Municipal Participant 8:

… we're actually going through the process of forming a stormwater utility.… In order to generate some revenue and be able to have some money to use on the stormwater, we're forming a stormwater utility. Studies are under way to make that happen, to determine what the assessments might be on various property owners. What it does is it will encourage property owners—and it will apply to big commercial properties and industrial properties that are mostly impervious. They will have the option of installing some green measures, and they will get credit toward their stormwater assessment by doing that. So they will actually pay less, and in exchange they will have to install some green measures. So that's pretty far along, but it is not adopted yet. We're hoping that by the end of the year it will be in place, so that it is fully up and running next year.

Three other participants discussed private developers as being responsible for implementing green stormwater infrastructure.

Municipal Participant 8:

As new projects come about through the city, there are green methods being implemented. Not by the city, but by developers.

Municipal Participant 10:

It helps catch debris in inlets, and as new developments come through, we ask them to install those also.

In one instance, a municipal participant made it clear that the local government was not responsible for the management of the green stormwater infrastructure. Instead, land owners or a homeowners association were responsible for maintaining the stormwater infrastructure.

> Municipal Participant 1:
> *There is one subdivision that has bioswales, but that's managed by the homeowner associations and that's about it.*

> Municipal Participant 1:
> *Stormwater ponds in new subdivision are managed by the homeowner associations. The city manages stormwater ponds that are in the business park that's owned by the city. There are two ponds for our subdivisions that were built in the 90s before the change in policy that had the homeowners association take care of it.*

The cost of these systems may be defrayed by a private developer. Additionally, the ongoing maintenance of these systems may also be funded by the landowner or an organization of land owners (homeowners associations). During the interviews, there was no mention of municipal involvement in maintaining or funding the green stormwater infrastructure specifically required for new construction. Though stormwater standards required for development have become more strict, direct financial or management involvement on the part of municipalities in adhering to these standards was not readily apparent. Responsibility was generally given directly to private developers or landowners, and voluntary financial or maintenance assistance from local government appeared to be lacking.

The stormwater utilities empowered community members to reduce their impact on stormwater runoff. Direct financial incentives, however, were the only kinds of incentives mentioned by the participants. Other benefits of green stormwater infrastructure may or may not be a selling point to these property owners. Moreover, as shown in other domains throughout the

data analysis, some municipalities are in poor financial shape and/or their residents do not consider stormwater management to be important. Therefore, stormwater utilities may not be universally accepted.

As participants were asked if the municipality used green stormwater infrastructure techniques, several of those who responded positively focused on the standards for new construction or other plans, such as the stormwater utilities. The general consensus among the participants was that these newly implemented systems constituted positive steps taken by the municipalities themselves. Though local governments may be involved in enforcing new standards, many of which derive from state and federal laws, they may not be directly involved in the implementation or funding of green stormwater infrastructure in new public development or on private property.

	Municipality											
	1	2	3	4	5	6	7	8	9	10	11	12
Green S.W.I. - More/Too Expensive			■							■	■	■
Upgrading S.W.I. - Too Expensive					■			■				
Green S.W.I. - Less Expensive			■					■				
L.O.F. hinders Green S.W.I.	■		■	■		■		■	■	■		
Funding allowed Green S.W.I.			■									■
S.W. Utility allows Green S.W.I.		■						■				
Private Devel. Pay for Green S.W.I.	■							■		■		

Figure 6.4: Financial Constraints and Opportunities for Green Stormwater Infrastructure. Shaded areas are topics that municipal participants specifically discussed. S.W.I. = Stormwater Infrastructure, L.O.F. = Lack of Funding, S.W. = Stormwater, and Devel. = Development

	Municipality											
	1	2	3	4	5	6	7	8	9	10	11	12
Use: **U.F. / Tree Plantings**		■	■									
Use: **Pervious Pavement**		■		■								
Use: **Rainwater Harvesting**		■										
Use: **Green Roofs**		■	■									
Use: **Rain Gardens**		■				■	■			■		
Use: **Bioswales**	■		■				■			■		
Use: **Constructed Wetlands**								■				■
P.P.: **Pervious Pavement**	■									■	■	
P.P.: **Rainwater Harvesting**									■			
P.P.: **Green Roofs**										■		
P.P.: **Rain Gardens**										■		
P.P.: **Bioswales**			■									
S.W. - Not a Priority			■				■		■			
S.W. - Priority if Prominent Issue							■	■				
Gray is Good if Meeting Regulations	■	■	■	■		■	■			■	■	
Gray is Good - Maintain Existing	■					■					■	■
Gray is Good - Upgrade with Gray		■	■					■		■		
Gray not Good - Green New Constr.			■	■		■			■			
Gray not Good - Green is Future				■	■						■	
Gray not Good - Green is Better			■									
Green S.W.I. - Small-Scale Solution		■	■									
L.O.S. hinders Green S.W.I.							■		■	■		
Green S.W.I. when Space Available								■				
L.O.S. doesn't hinder Green S.W.I.		■										
Private Prop. hinders Green S.W.I.		■			■							
Private Prop. success Green S.W.I.		■							■			■
Soil type hinders Green S.W.I.							■			■		
Green S.W.I. - More/Too Expensive			■							■	■	■
Upgrading S.W.I. - Too Expensive					■			■				
Green S.W.I. - Less Expensive			■					■				
L.O.F. hinders Green S.W.I.	■		■	■		■		■	■	■		
Funding allowed Green S.W.I.			■									■
S.W. Utility allows Green S.W.I.		■						■				
Private Devel. Pay for Green S.W.I.	■							■		■		

Figure 6.5: Data analysis matrix.

Chapter 7

Relevance of this Study

As might be expected, several of the opinions expressed by the municipal participants during the interview process are discussed in similar studies addressing drivers for and barriers to green stormwater infrastructure. Other topics that include and/or encourage green stormwater infrastructure (low-impact development, water-sensitive urban design, green infrastructure without particular focus on stormwater, etc.) have also been studied with similar results. The specific drivers and barriers identified through the data analysis are discussed in the context of the relevant literature in this section.

Summary of Findings: Drivers for and Barriers to Green Stormwater Infrastructure

Chapter 6 provides an analysis of the 12 interviews in terms of the 12 unified domains. Each of these domains provides a summary of findings in greater depth. To complete this study, the identified drivers and barriers are combined and summarized below to allow a discussion of the relevant literature to be more fully integrated.

Drivers for Green Stormwater Infrastructure

- Understanding of green stormwater infrastructure in the context of individual communities and as a larger concept
- Failure of existing gray stormwater infrastructure
- Federal and state regulations
- Availability of public space
- Private property

- Perceived cost of green stormwater infrastructure
- Available and alternative funding

Barriers to Green Stormwater Infrastructure

- Misunderstanding, lack of clear definition of green stormwater infrastructure
- Resistance-to-change attitude
- Lack of public support
- State and federal regulations
- Techno-fixes for failing gray stormwater infrastructure
- Perception that green stormwater infrastructure is a small-scale solution
- Lack of available public space
- Private property
- Soil characteristics
- Perceived costs of green stormwater infrastructure
- Lack of available funding

Relevance to Existing Literature

Understanding and Defining Green Stormwater Infrastructure

In most cases, the participants who expressed a significant understanding of green stormwater infrastructure were part of communities that had already implemented or were planning to implement multiple green infrastructure techniques. It was expected that municipal employees in municipalities using green stormwater infrastructure would be responsible for their oversight and would, therefore, understand the reasoning governing the use of these techniques. Other participants, however, failed to clearly identify what green stormwater infrastructure meant to them and/or they referred to a lack of understanding among municipal residents or other

stakeholders. An absence of a uniform definition is seen as an institutional barrier hindering individuals from understanding the benefits of green stormwater infrastructure.

The online *Oxford University Press Dictionary* does not provide a definition for *green infrastructure*, let alone *green stormwater infrastructure* (notably, phrases are normally not defined in dictionaries). Oxford's most applicable meanings for each of the words comprising these phrases are defined as follows:

> Green (adjective):
> Covered with grass or other vegetation; concerned with or supporting protection of the environment as a political principal; not harmful to the environment.
>
> Stormwater (noun):
> Surface water in abnormal quantity resulting from heavy falls of rain or snow.
>
> Infrastructure (noun):
> The basic physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) needed for the operation of a society or enterprise.

Another readily available source for local municipalities and their employees is the model set by Philadelphia. The Philadelphia Water Department (2010) website identified its own definition of green stormwater infrastructure in this way:

> Our definition of green stormwater infrastructure includes a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some cases release a portion of it slowly back into the sewer system.

The United States Environmental Protection Agency (2012b) offered another online definition of green infrastructure in the context of water infrastructure:

> Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water.

As shown, green stormwater infrastructure has varying definitions. There are consistent characteristics, including the use of vegetated areas to address stormwater runoff, but several other variables are left in question. Scale, political and social involvement, the physical and biological roles of water, appropriate applications, etc., are not clearly established.

Numerous studies acknowledge that a lack of understanding of green stormwater infrastructure hinders its use and that a more complete understanding of the numerous benefits of green stormwater infrastructure encourages its implementation (CWAA, 2011; Clements & D'Amato, 2010; Lee & Yigitcanlar, 2010; OEC, 2007; Roy et al. 2008; Stockwell, 2009). The complex processes involved in establishing a definition of green stormwater infrastructure, however, are readily discussed in the related literature.

This issue is not unique to the findings of this study. In its 2011 report, "Barriers and Gateways to Green Infrastructure," the Clean Water America Alliance (CWAA) (2011) defined the term "green infrastructure" as a barrier to implementing such practices. Based on its survey of 200 individuals, the CWAA found that an "overall lack of education, knowledge, and experience of green infrastructure design, maintenance, and benefits at the local, state, and even federal level" inhibited the growth of green stormwater infrastructure (16). In the CWAA report, the absence of a sufficient definition began with a lack of consistent training for government employees. Other respondents reported that the definition of green stormwater infrastructure was

too stringent and could actually complicate decision-making processes in regard to whether to use green infrastructure methods for stormwater run-off.

An all-encompassing definition of green stormwater infrastructure applicable to each specific project may be impossible to construct. As discussed in the literature, even a simple written definition may be too restrictive such that it actually hinders the growth of green stormwater infrastructure. Understanding green stormwater infrastructure is viewed as a driver of implementation, but understanding how to convey the objectives and benefits of green stormwater infrastructure to municipal employees and citizens alike is a critical component that does not appear to have been communicated consistently.

Resistance to Change

During the interview process, some individuals referenced a resistance-to-change attitude on the part of other members of the community. Additionally, some of the participants themselves, who were not as engaged in the discussion of green stormwater infrastructure, may also have been resistant to deviating from the familiar gray stormwater infrastructure that persists within their respective communities.

Whether it is a lack of trust in a new technique or just the anxiety caused by unfamiliarity, a willingness to embrace green stormwater infrastructure is certainly not universal. This resistance-to-change attitude is a barrier commonly cited in the literature (CWAA, 2011; Ellis et al., 2010; Madden 2010; OEC, 2007; Roy et al., 2008; White 2010). The Oregon Environmental Council (2007) described the role of resistance to change in stormwater management practices as follows:

> Changing the standard way of doing something is difficult no matter what the issue is, and stormwater management is no exception. Among all the people involved in the process, including elected officials, planners, engineers, inspectors, developers, contractors, designers, customers, and the general public, there are some individuals who embrace the shift toward more sustainable practices and others who either don't understand it or are resistant to change for one reason or another. (p. 24)

There is no quick, definitive approach to overcoming the resistance-to-change barrier described in the literature. Some recommendations involve further education in regard to green stormwater infrastructure's benefits and establishing pilot projects to help alleviate any associated skepticism (CWAA 2011; OEC, 2007; Roy et al. 2008). A strong individual or groups of individuals assigned the role of community outreach to encourage public education of these practices is also desired in support of municipalities' efforts in this regard (OEC, 2007; Madden, 2010; White, 2010). Above all, a consistent effort from advocates in terms of green stormwater infrastructure is important if substantial changes are to be made over time.

Perceived Lack of Public Support

During discussions concerning how residents prioritized stormwater management, there was a general consensus whereby most of the participants expressed the opinion that most residents did not consider managing stormwater to be an important issue. Stormwater became a priority only when residents were directly impacted by the negative consequences of urban water management. Otherwise, as some of the participants stated, residents just wanted stormwater to be taken care of with as little cost to them as possible. Related literature (Brown & Farrelly, 2007; CWAA, 2011; OEC, 2007; Roy et al., 2008) specifies that public support is needed to transition

to green stormwater infrastructure, and the general assumption is that this support does not exist. Other studies, however, contest this notion.

A survey conducted by Giacalone et al. (2010) of 1,599 residents in four geographic regions of South Carolina aimed to "determine the overall level of concern about water quality" directly related to stormwater (93). The results of the survey suggest that the majority (73.8–82.1%, depending on region) of respondents were concerned with pollution in and the environmental quality of local streams and waterways. Similarly, in a survey conducted in the Chesapeake Bay watershed, 85% of the 1,988 polled residents expressed concern about pollution in their local streams and waterways (McClafferty, 2002).

The survey results from South Carolina and Chesapeake Bay watershed residents seem to contradict the opinions expressed by the municipal participants in the Delaware River Basin, suggesting that the participants' assumptions about their communities' feelings toward stormwater may not be factually based. On the other hand, the results of the two surveys referenced here may suggest that when residents are asked about issues related to stormwater, their answers may not accurately describe their actual behavior or everyday feelings. Another important variable to distinguish is that the two surveys specifically discussed water quality and water pollution. Although survey questions discussing these topics cannot readily be interchanged with opinions on stormwater management, both surveys included stormwater as a subtopic.

State and Federal Regulations

About two-thirds of the participants referenced state or federal regulations when describing their current stormwater management systems and the role of green stormwater infrastructure in their current approaches to and future plans for managing urban runoff. In some cases, the participants described a lack of current advancement toward green stormwater

infrastructure in their communities because, as long as they were meeting regulations, there was little incentive to change their systems. Others referenced state and federal NPDES regulations as a primary driver for their transition to green stormwater infrastructure. Municipal practices seemed to be largely dictated by government regulations and can be viewed as both a driver for and a barrier to implementing green stormwater infrastructure.

Many (if not most) of the relevant studies discussing the implementation process of green stormwater infrastructure at the municipal level reference national, state, watershed, or other regional regulations as a primary motivator for putting green stormwater infrastructure in place. Local regulations must meet these larger umbrella requirements, and additional requirements can be self-imposed. Understanding and adhering to these standards is required for municipal employees who are responsible for managing and maintaining stormwater systems.

In related literature, several advocates for green stormwater infrastructure express a need for stronger regulations that require or encourage the use of green stormwater infrastructure on a variety of spatial and political scales (Brown & Farrelly, 2007; CWAA, 2011; Dunn, 2010; Lee & Yigitcanlar, 2010; Roy et al. 2008). However, as Barry noted in 1970, comprehensive water regulations are often controversial because there are numerous variables specific to local bodies of government. Though complex hydrologic issues in stormwater management are perhaps better understood now than at any other time in U.S, history, state and federal regulations tend to lag behind in regard to actually enforcing best management practices.

Gray Infrastructure Techno-Fixes

Four of the municipal participants discussed gray stormwater system upgrades when describing their communities' infrastructure. As aging infrastructure inevitably fails or requires major renovations, there are opportunities for green stormwater infrastructure, simply because the

existing infrastructure must be replaced. Another option is to replace existing gray stormwater infrastructure with newer and more technologically advanced gray stormwater infrastructure.

Improved gray stormwater infrastructure techniques may curb some of the existing negative impacts of the urban environment on water. Techno-fixes to current gray stormwater infrastructure are potentially a major barrier to the growth of green stormwater infrastructure practices. Improved gray stormwater infrastructure may allow municipalities to adhere to regulations without realizing the additional benefits that can accrue from green stormwater infrastructure.

Chocat et al. (2007) described numerous future scenarios for the role of stormwater in the urban environment. One possible situation referred to as the "technocratic scenario" features urban stormwater managed through feats of engineering as follows:

> By applying the proven technology, coupled with redundancy and large safety factors, they make sure that the system does not fail. The solutions are not necessarily cheap, but they are robust and impressive from the technological point of view. Thus, this scenario is basically conservative, even if ambitious engineers might get a chance to apply advanced technologies to water systems, e.g., automation, control, robotics; real-time operation; third generation of communication—computer; use of mobiles phones; use of biotechnology for water quality control; new field measurement and laboratory equipment, etc. (p. 279)

The scenario described is founded on the fact that this is largely the approach taken to managing urban stormwater for the last two centuries (Chocat et al., 2007; Clements & D'Amato, 2010; CWAA, 2011; Ellis et al. 2010). The purpose of green stormwater infrastructure is quite the opposite: it focuses on decentralized systems instead of finely tuned products of controlled engineering. It is likely that gray technologies will continue to advance and continue to deter the

use of naturalized systems as long as green stormwater infrastructure is determined to be inappropriate in specific applications.

Scale of Green Stormwater Infrastructure

Some of the participants in this study described green stormwater as simply a small-scale solution. And, many of the proponents of green stormwater infrastructure are discouraged by the limited implementation of such practices in the urban environment. Using one or a few techniques is just the first step in having a significant influence on urban water, though the summation of numerous small-scale green practices can have a positive impact on an urban watershed. The scale of techniques used could vary greatly, and "for green infrastructure to be successful, it must be addressed at all scales, from site-specific and neighborhood to regional and watershed levels" (CWAA, 2011). Similarly, Tzoulas et al. (2007) described green infrastructure as a summation of numerous spatial scales:

> It can be considered to comprise of all natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales. (169)

Scale, unless referencing a lack of large-scale implementation, is rarely referred to as a negative characteristic of green stormwater infrastructure in the literature. Some advocates argue that green stormwater infrastructure can be successful on a very small scale (Clark, 2008; Dunn, 2010; OEC, 2007; Roy et al., 2008). In the present study, however, some of the participants' attitudes, however, were interpreted as meaning they considered to view small-scale as a sign of inefficiency, and that specific perception is not readily discussed in the within the relevant literature.

Space: Public and Private

Another reoccurring topic that surfaced during the interview process was the lack of available space. A lack of public space was generally viewed as an impediment to installing green stormwater infrastructure. Implementing green stormwater infrastructure on private property was viewed as a barrier for some of the participants but an opportunity to implement green stormwater infrastructure for other participants. Some participants noted that their communities were either built out or were not experiencing any new development. The lack of available space conundrum is not thoroughly explored in the explored body of literature. Retrofitting existing infrastructure and installing green stormwater infrastructure, in some cases, may take up more public land than traditional in-the-pipe gray stormwater infrastructure would, but green infrastructure may make for a more flexible use of the required space. The implementation of green stormwater infrastructure on private property has become more feasible with the adoption of stormwater utilities and other incentive programs on the part of small municipalities. Additionally, as discussed, when gray stormwater infrastructure ages and ultimately fails, new stormwater infrastructure is required and can be viewed as another location for green stormwater infrastructure practices (Bauers, 2009; CWAA, 2011; OEC, 2007; Roy et al., 2008).

Soil Characteristics

The interview process revealed two concerns related to soil and infiltration in regard to stormwater runoff. One participant was concerned that infiltration would pollute underground water sources in the city based on the region's karst geology. The second participant had the opposite concern: that the heavy clay-based soil structure within the municipality was too impenetrable for infiltration to be effective.

Karst geology, as one of the municipal participants specifically stated, may be troublesome because of rapid infiltration into low-lying aquifer recharge areas. This geology is more susceptible than are others to groundwater contamination, as filtration is naturally minimized (Stephenson & Beck, 1995). Stephenson et al. (1999) monitored a fresh water spring in karst geology in close proximity to a major roadway. They concluded that the spring was more contaminated by heavy metals, solids, and other pollutants than expected in most other geologies.

Barfield et al. (1998), however, concluded that over 90% of sediment and chemicals can be trapped through natural grass plantings in karst geologies. Liu (2008) conducted a review of multiple monitored sites impacted by runoff pollution and mitigation best management practices including the use of grassed and otherwise vegetated buffer areas. The results showed that these measures yielded a significant reduction in sediment and pollutant transport achieved with substantial vegetation plantings. The EPA (1993) has offered general standards for best management practices in karst geologies, including the use of a series of shallow retention-infiltration areas, swale conveyances, and heavily vegetated areas where stormwater runoff spreads out over a large horizontal surface.

The second concern discussed by a municipal participant was that heavy clay-based soil makes infiltration problematic. Hsieh and Davis (2005) expressed the same concern regarding the impermeability of clayey soils, saying that "If permeability is low, a significant fraction of the

runoff would simply bypass the bioretention, negating any possible delay of peak discharge and reduction of contaminants" (p. 1522). There are solutions, however, to encourage infiltration in soils with high clay concentrations. Soil media can be altered or constructed to encourage infiltration, and under drains can be installed to transport infiltration to a secondary filtration location (UC Davis, 2012).

Still, using infiltration practices in karst geologies is generally discouraged because groundwater quality is so vulnerable (Weiss et al., 2008). Infiltration in heavy clay-based soils is difficult and may add costs to a project (UC Davis, 2012). Numerous studies have shown that infiltration practices can still be used if special attention is paid to addressing the stated concerns (CWAA, 2011; OEC, 2007). In particular, soil constraints seem largely fixated on infiltration. Infiltration, however, is just one component of green stormwater infrastructure. Even given these concerns, there are undoubtedly opportunities to explore alternative green stormwater infrastructure techniques where infiltration is deemed inappropriate or difficult.

Perceived Costs of Green Stormwater Infrastructure

Several of the participants discussed the high financial costs associated with green stormwater infrastructure techniques. Participants who were given a reduced upfront cost were more inclined than were others to invest in green stormwater infrastructure practices. The construction of any infrastructure has some upfront financial costs. However, two specific topics associated with financial costs were discussed by the participants: the cost comparison between green stormwater infrastructure and gray stormwater infrastructure, and upfront costs versus long term value.

Upfront costs are specific to the project location and green stormwater infrastructure techniques being used. For example, installing a green roof on an existing building may be more

expensive than using rain gardens on the same site. By the same token, gray stormwater infrastructure is also site-specific in terms of upfront costs. The EPA and the American Society of Landscape Architects (ASLA) recently released 479 green stormwater infrastructure case studies gathered from 43 states, Washington, DC, and Canada. Submissions were asked to address this question: “Did use of green infrastructure increase costs?” In response, 44.1% of the submissions indicated a reduction of project costs by using green infrastructure, whereas 31.4% of the case studies stated that using green infrastructure did not influence costs. Less than 25% of the projects indicated an increase in project costs incurred using green stormwater infrastructure (ASLA, 2011). Though it is impossible to determine the cheaper management technique in terms of upfront costs without analyzing the variables presented at each site (CWAA, 2011; MacMullan & Reich, 2007; OEC, 2007), the ASLA case studies do provide encouraging statistics.

Maintenance is another component of infrastructure, and its financial impact should be considered in the planning stages of a project. As discussed by the participants, they are generally responsible for maintaining the existing gray stormwater infrastructure in their communities. Green stormwater infrastructure must also be maintained, but in most cases doing so entails an entirely different process (Clark, 2008), and it should be noted that working with plants and living systems is likely to require new training for municipal workers and additional upfront costs. Longer-term comparisons between the maintenance costs of green and gray stormwater infrastructure are referenced in several studies as an area in need of further attention (CWAA, 2011; Jaffe, 2010; MacMullan & Reich, 2007; OEC, 2007; Roy et al., 2008).

The most apparent economic benefit of green stormwater infrastructure comes in its long-term social and environmental benefits and the values associated with them. Several studies have focused on determining the value of green stormwater infrastructure and its ecosystem services. The Center for Neighborhood Technology (2010) reported that a single green roof in an urban environment can provide a total annual benefit of over $700. Only a fraction of this benefit is tied

directly to water, and it is important to remember that green stormwater infrastructure provides many non-hydrologic benefits. In the Delaware River Basin, Philadelphia's movement toward green stormwater infrastructure was propelled by a cost–benefit analysis, according to which green stormwater infrastructure offered a net financial benefit more than twenty times the alternative gray stormwater infrastructure management technique specified (Stratus, 2009).

Project Funding for Green Stormwater Infrastructure

Multiple participants referenced a lack of available funding as a barrier to implementing green stormwater infrastructure in their communities. If municipalities had more money available to overhaul their stormwater management systems, the participants generally believed that green stormwater infrastructure would be used to a greater extent. Perhaps not coincidently, of the projects described by the interviewed individuals, the source of funding was often identified. As expected, a lack of available funding for green stormwater infrastructure is also identified in the relevant literature as a barrier. State and federal grants are available, but they are few in number and highly competitive. Private or non-profit funding opportunities are also available, but awareness of and access to these funding opportunities is limited, especially for the smaller municipalities (CWAA, 2011; Ellis et al., 2010; Roy et al. 2008; Stockwell, 2009).

Of the studied municipalities, some have incorporated stormwater utilities, which shift some stormwater infrastructure related costs from the government budget directly to individual property owners; as a fee dependent on the characteristics of the individual property owners' land. From a municipal government perspective, there are multiple benefits to creating a stormwater utility. Brisman (2002) pointed out that property owners become financially responsible for stormwater runoff from their properties and its burden on municipal facilities. Larger industrial or commercial sites, which are likely to have greater stormwater impacts, are

required to pay more than other municipal residents are. Municipalities can offer land owners credits for reducing their impact (i.e., using green stormwater infrastructure techniques). In return, land owners can help reduce the negative effects of urban stormwater runoff while also becoming more aware of their individual impact on the system (Clements & D'Amato, 2010; CWAA, 2011; Dunn, 2010; OEC, 2007). Implementing stormwater utilities, however, requires a strong political will and public support and may take time to come to fruition in some communities (Brisman, 2002).

Another way municipalities in this study have encouraged the use of green stormwater infrastructure, without undertaking any direct financial burden, is by requiring new developers to pay for the installation and maintenance of green stormwater infrastructure techniques through local ordinances. This is effective for new development, yet it does not particularly address the costs associated with existing infrastructure (CWAA, 2011).

Chapter 8

Discussion

Limitations of this Study

Due largely to time constraints, only 12 of the municipalities in the Delaware River Basin had participating individuals in this study. Based on such a small sample size, it is impossible to draw broad conclusions about the role of green stormwater infrastructure in the Delaware River Basin. It is also impossible to assume that the collective opinions of 12 participants can capture the opinions of similar professionals in adjacent communities, meaning different municipal employees from different municipalities may differ in their opinions on the given issue. Furthermore, the Delaware River Basin has specific watershed characteristics, and additional variables must be accounted for when relating the data gathered from this study to municipalities or stormwater management entities in other watersheds. Reaching such conclusions, however, was not the objective of this study. Instead, the study's purpose was to obtain the opinions of additional individuals to strengthen the data and, consequently, the data analysis.

Another limitation of this study pertains to the participants themselves. Although the participants were identified based on their expertise on stormwater management in their municipalities, they only offer perspectives from only one group on a complex social and political issue. Therefore, the participants do not necessarily adequately represent their respective municipalities. Other community stakeholders, politicians, residents, or even employees from the same offices as the participants may have differing opinions on specific topics. Ideally, various perspectives from individual communities should be collected to further understand the barriers and drivers related to green stormwater infrastructure. It is important to remain cognizant of the

fact that the data are subjective, and even seemingly objective data (for example, descriptions of existing stormwater infrastructure) may be incomplete or misconstrued. Cross-checking statements made by participating individuals with planning documents, direct observation, and other methods could challenge or reinforce the opinions of the participants.

Finally, in terms of scientific research, qualitative data analysis offers other limitations that have been identified and defended exhaustively in the literature. Researchers analyze the data to the best of their ability, but it is impossible for researchers to remain completely unbiased in interpretation (although, that is the aim in doing so). Transcribed interviews are included in the Appendix to allow readers to make their own interpretations of the data. The data analysis is presented in a way that renders it as transparent as possible. As this topic is reliant on the decisions of people and the perceived values of individuals and communities, qualitative data gathering and analysis was viewed as the most appropriate method of conducting this research.

Executive Summary and Recommendations

This study used qualitative data analysis to assess of the current perceptions and understanding of green stormwater infrastructure in 12 municipalities in the Delaware River Basin. The opinions of 12 municipal participants provided insight into the current state of their municipal stormwater management systems and perceptions related to implementing green stormwater infrastructure in their respective communities. The study revealed a number of barriers and drivers for green stormwater infrastructure; specific topics that may be addressed by advocates of green stormwater infrastructure when communicating with municipal decision makers. Below is a summary of these topics accompanied by the researcher's recommendations.

As shown through the data analysis, green stormwater infrastructure is not a concept that is readily understood by every individual involved in the decision process or other individuals

who are affected by the negative impacts of urban runoff. The level of understanding in regard to green stormwater infrastructure varied among the 12 participants, each of whom was a director of a public works office or another stormwater specialist in the local government. Based on occupation alone, it could be assumed that the participants would be responsible for this body of knowledge. The participants from municipalities that used green stormwater infrastructure evinced a greater understanding of green stormwater infrastructure's expanded role in their communities. Without being educated in green stormwater infrastructure, the option of doing things more sustainably than traditional gray stormwater management is inherently limited. This notion is reflected in the literature. It is, however, difficult to place blame strictly on these professionals, as messages conveyed to them about green stormwater infrastructure may be too vague, too strict, or non-existent. Therefore, local government officials in general may be misinformed. Education is a key component in efforts to encourage further implementation of green stormwater infrastructure, but an effective education process should begin with the development of successful teaching tools.

If local government officials are well-informed, there may be greater opportunities for public outreach and increased public support. According to the literature, the negative effects of traditional stormwater infrastructure (degraded quality, flooding, etc.) are issues that concern many residents of a watershed. Some municipal employees believe that residents do not care about, or are at least uninterested, in stormwater management. Residents may not fully understand the relationship between stormwater runoff and hydrologic issues. As already established, green stormwater infrastructure alleviates several urban water issues. Public officials, at least in some municipalities, may not be effectively conveying this message to their community members, which could limit future or immediate support for the use of green stormwater infrastructure practices.

Green stormwater infrastructure, put in the context of the residents' homes, their local municipalities, and other factors that they encounter on a daily basis, may instead encourage further support and interaction with municipal governments for sustainable stormwater management practices. This could be realized through public outreach and education, fueled by informed municipal employees, or as the literature suggests, public demonstration projects that include an educational component in their design.

The overall use of green stormwater infrastructure described by the participants was underwhelming, compared to the most published and championed municipalities (Portland, Philadelphia, etc.). Green stormwater infrastructure, at least according to the 12 participants, is not the government's standard approach. At least on the surface, however, some of the municipalities seem to be heading in that direction. Unfortunately, the ideas and ideals discussed by the participants do not provide the same environmental benefits as implemented green stormwater infrastructure techniques. It is impossible to know, at this point in time, the extent of the impact green stormwater infrastructure will have on these municipalities in the foreseeable future. Although it is unfair to make generalizations about other municipalities based on this study, there is little evidence to suggest that many of the other local governments in the region have fully embraced green stormwater infrastructure either.

From a more optimistic point of view, though, we should note the far less advanced state of green stormwater infrastructure in these communities even ten years ago. It is fair to assume that there is now increased use of more sustainable approaches to stormwater management, with very few participants discussing green stormwater infrastructure as an entirely foreign concept in their municipalities. Revisiting these municipalities in the future would certainly be a good exercise, but how far in the future? The negative impacts of urban stormwater runoff are being felt today (and have been for centuries) in many urbanized watersheds and are almost certain to

persist until a comprehensive shift in regard to stormwater infrastructure and management take place.

Pushing changes in water management, as the participants and the literature suggest, is tied to progressive regulations. When discussing their current stormwater systems, several participants referenced state and federal regulations as benchmarks for satisfactory stormwater management. Likewise, it is reasonable to surmise that stronger regulations would rapidly increase the use of green stormwater infrastructure in some instances. Throughout the history of American regulations related to water quality, however, putting regulations in place and enforcing them has entailed complex processes such that doing so has never been a "quick fix." Changes in policy at the municipal government level, where social and political systems may be simpler and more sensitive to local variables could affect necessary changes more rapidly. But, changes to local government standards are unlikely to occur without a direct or perceived incentive. Though one proven incentive is the need to adhere to state and federal government standards, for change to take place more quickly, the other social, economic, and environmental benefits of green stormwater infrastructure must be emphasized as part of an overall program to achieve buy in and further progress.

Another interesting finding related to the comparative readiness of the participants to reference specific regulatory details when describing their stormwater systems. As discussed, though not all the participants fully understand what green stormwater infrastructure is or what it can offer to community members. There is little doubt, however, that they were educated in regard to the municipal, state, and federal regulations. Though quickly overhauling state and federal regulations may be unrealistic, it is apparent that government systems can act as effective educational institutions. Therefore, higher levels of government could be drawn as educational resources in order to further encourage the involvement of municipal employees and other consultants in learning about stormwater management alternatives. As discussed, though, the

messages conveyed would benefit from consistency in terms of delivery and in terms of clear and appropriate definitions.

The physical constraints identified by the participants included scale, space, property ownership, and soil characteristics. Based on the literature and the experiences of some of the municipalities in this study, opportunities can be highlighted to counter each of these perceived barriers. Scale, in this context, referred to green stormwater infrastructure as constituting only a small-scale solution. Green stormwater infrastructure relies on connecting a number of sites of all scales, small or large, in order to bring about a larger-scale impact. A lack of public space for new infrastructure may be a constraint, but retrofitting existing gray stormwater infrastructure may require little or no additional space. Private landowners were viewed as impediments by some of the participants, but others discussed the implementation of green stormwater infrastructure techniques on private property, which presents more available space for green stormwater infrastructure practices. Soil constraints, as described by two of the participants and in the literature, can hinder infiltration techniques in some circumstances. Infiltration, however, is only one component of green stormwater infrastructure, and where infiltration is difficult, green stormwater infrastructure does not have to be eliminated from discussion.

The municipalities vary in terms of the particular physical characteristics likely to contribute to making implementing green stormwater infrastructure a complex process. In this study, however, it is conceivable that no physical constraint described would make implementing green stormwater infrastructure impossible. Several perceived physical constraints could be overcome based on more fully educating municipal employees in regard to the advantages of green stormwater infrastructure and ways to make implementing such a system feasible.

Several of the participants believed that green stormwater infrastructure would be viable in their communities if funding were available for installation. Some participants believed that green stormwater infrastructure was too expensive to incorporate into the infrastructure of their

municipalities. As the literature shows, green stormwater infrastructure is not necessarily more expensive in terms of upfront costs and it is almost always more valuable in terms of ecosystem services. Funding options are available, albeit they are competitive and require motivated local governments.

One of the most significant barriers to implementing green stormwater infrastructure may not be the cost or lack of funding, but rather the untested assumption that green stormwater infrastructure is simply not financially feasible. There remains a great opportunity to connect local governments to funding opportunities, either through liaison organizations and institutions or through mutual outreach efforts between municipal employees and the bodies offering financial aid. Even if funding is unavailable, long-term cost–benefit plans could still be created for every municipality and, as a result, green stormwater infrastructure could take on a larger role in master plans for future planning projects.

Other municipal participants described alternative strategies for implementing green stormwater infrastructure that would take the financial burden off local governments. Stormwater utilities taxed land owners for their stormwater runoff (tax relief was awarded based on land owner's use of green techniques) or municipalities required developers to install best management practices. This seems to be most effective in creating new infrastructure and dealing with private property, but these methods deflect issues directly related to existing municipal infrastructure.

Municipalities may be eager to claim that they have moved (or are moving) toward green stormwater infrastructure without fully engaging potential uses. It is certainly possible that though municipalities may welcome the reputation of being "sustainable," they may not be taking the necessary steps to actually deserve that reputation. This mentality focuses on preventing future harm rather than fixing the environmental issues related to existing infrastructure. Unfortunately, the existing traditional urban infrastructure is often the main culprit in regard to

the negative impact of stormwater management practices. If more municipal participants had a deeper understanding of green stormwater infrastructure, it is plausible that they would be more inclined to focus on their own existing infrastructure and on preventing further environmental degradation in new construction.

Conclusion

This study used qualitative data analysis to identify the perceived drivers of and barriers to green stormwater infrastructure in 12 municipalities in the Delaware River Basin. The attitudes varied fairly dramatically among the participants, but many underlying themes emerging. In some cases, the findings directly correlated with the literature focusing on green stormwater infrastructure. In other cases, the participants' opinions could not readily be connected to the literature.

In conclusion, the drivers of and barriers to green stormwater infrastructure are tied directly to one overarching factor: communication. Many barriers could be overcome with a stronger knowledge and supporting cast. Green stormwater infrastructure and its advocates need a stronger voice in local governments in order to have short- and long-term impacts on local stormwater infrastructure. Communication is necessary for effective education. Education is required to overcome social barriers (resistance to change, perceived lack of public support, etc.) and perceived physical barriers (scale, space, etc.). As more members of a community realize the advantages of green stormwater infrastructure for themselves as individuals and for the community as a whole, the demand for green stormwater infrastructure practices could increase. It may be a slow process, but understanding the benefits of green stormwater infrastructure and encouraging a greater desire to combat the negative impacts of traditional urban infrastructure is necessary for large-scale change.

This thesis has (amongst other things) revealed that landscape architects and other advocates for green stormwater infrastructure should be proactive in their communities. Raising awareness of the negative impacts of traditional stormwater management is important. Describing the benefits of green stormwater infrastructure (including the ability to alleviate those negative impacts) to local governments, community members, and other municipal stakeholders is another key component. In the researcher's opinion, however, it is most important to relay these messages in a language that each party can understand and in ways that relate to their particular values. This study constitutes an initial step in understanding the state of green stormwater infrastructure in 12 municipalities in the Delaware River Basin, and this information can be used to aid the future implementation of green stormwater infrastructure and inform future studies related to green stormwater infrastructure.

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Appendix: Interview Transcriptions

Municipal Participant 1

Do you have any questions for me before we begin?

> *No I'm fine.*

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

> *Stormwater ponds in new subdivision are managed by the homeowner associations. The city manages stormwater ponds that are in the business park that's owned by the city. There are two ponds for our subdivisions that were built in the 90s before the change in policy that had the HOA take care of it. So we only manage seven ponds. Stormwater runoff from the streets and highways, all we do with that is keep the pipes clean. There is nothing else involved with that source of stormwater flow.*

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

> *No, not at this time. There have been some plans submitted through private management for pervious pavement and so forth, but they have been rejected by the city– in one case, the Fire Marshall. That was for a building, they wanted to put in pervious pavement along the building in the fire lane and not have any traffic there. But the Fire Marshall said no, they didn't trust it. They wanted solid pavement. We don't have any management like that in the city. There is one subdivision that has bioswales, but that's managed by the HOA and that's about it.*

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

> *We deal a lot with the conservation district, so managing and maintaining what we have in place is a big part of it. Like I mentioned, there had been a couple of plans for those types of management strategies, but they were shot down relatively early in the process. Last year, we did put together a committee of sorts to help develop standards that the community could live with to limit total loading on the [local] river. We looked at what sources are there that contribute loads to the rivers. Whether it be agricultural or stormwater loads from the city. That was for more of a longer term plan.*

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

> *You know, we're a small city, under 10,000 so we don't need to meet NPDES regulations for our total maximum load or anything like that. I don't think people are necessarily opposed to it, maybe they are just used to the way things have been done. You know, I don't think the Fire Marshall represents all of the decision makers, but that is part of it. Also, there isn't a lot of money coming in, so doing those types of things can be difficult.*

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

> *Yeah, the planning and zoning boards might be able to help you out there. The mayor's office might be good to talk to.*

Municipal Participant 2

Do you have any questions for me before we begin?

> *No, go ahead, let's get it done.*

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

> *Well, the municipality itself substantially has a combined sewer system. Over the last decade, we have engaged in a series of what are called in–pipe strategies for controlling overflows from that system. Our combined sewer networks have built–in overflows in them by design. In light of new TMDL allocations and things like that, we have been working on limiting the amount of overflows that occurs so we can meet our total maximum daily load obligations in the area of streams. So there are two strategies that we've used, well I should say we there are three, but the main strategies are storage; store and release strategies, which involve the construction of large underground tanks. Where, during a rain event flow goes in, and at the cessation of the event the water is let out of there, back into the sewer network. The other is actually an in–pipe strategy that is called the real–time control. That actually utilizes the capacity of the sewer network itself. It can store water during a rain event and that storage is really managed through a series of weirs and active gates and things like that. They are tied to a central computer control network. So that's our real–time control strategy which we will be implementing and starting up in the next month or so. The third strategy, which has been at a much smaller scale, has been in certain parts of the city. Well, one part of the city I should say… actually two parts of the city. We have done some, what are known now as "green solutions" which involve basically trying to manage stormwater on property so that runoff from roofs and things like that aren't allowed to run directly into the sewer network. That third strategy will probably became a much larger component of efforts as time goes by but it's a much slower process because you're dealing with small scale. When you deal with a smaller scale, you're dealing with many more players. So that's basically it.*

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

> *We've done two kinds of things. We've done some porous pavements on parking lots at a small scale. We've done, basically on larger homes with enough garden area, we've done*

rain gardens. We've done green roofs, to a small extent. Cisterns, not that many; there have maybe been a cistern or two installed on one of the properties that we've worked on but not that many. We've actually done work on a library where we actually do have a cistern and sort of a rain-barrel-type arrangement; it's a large system. Again, in the scheme of things they are all capturing water from relatively limited areas. We haven't done any green infrastructure along roadways yet, although that is a strategy that we might pursue as time goes on. That would involve construction of tree beds and things like that and some combination of that and porous paving or some kind of storage mechanism that runs water into the tree beds. We also have an urban forestry program, and one of the objectives there is to increase the tree canopy, and that really ties into the whole stormwater mission.

So there has been further discussion of utilizing green infrastructure to manage stormwater as future strategies?

Yeah, they're all part of what we like to call the "tool box of ideas" but you have to look at the opportunities. A key strategy for us in terms of the future is to take a look at the particular watersheds—or the sewersheds, I should call them. Within the city there are many. The drainage network within the city consists of several geographic areas. One of the things we're focusing on is which of these areas give us the biggest bang for the buck, in terms of impact. So it's those kinds of studies we're looking into right now. The benefit would be the greatest reduction in runoff entering the local water body.

What barriers do you believe prevent large scale inclusion of green stormwater infrastructure in your community?

Private property is a large component of runoff; it's really dealing with institutional issues of engaging with private property owners. We do have a stormwater utility, which we've introduced three years ago. We do charge people on a basis of their footprint, their discharge runoff footprint and as a consequence of that program, there is incentive for property owners to try to reduce their footprint because we give them a credit. We have a credit program for that. So there are incentives in place, but are those incentives alone

enough to drive people toward doing green things with their property is an open question.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Well, you'd want to reach out to city council members I'd say.

Municipal Participant 3

Do you have any questions for me before we begin?

No, not really. I'd be interested to see where you're headed, but why don't you ask me the questions first, and you can fill me in after the fact.

How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

We basically, for lack of better terms, send it to local waterways. There was a time in this city where a good portion of the collection was combined, that would be about 30-35 years ago. With some federal and state grants that the city received, they separated a lot of it. We're down to less than 5% combined sewer here. So, to answer the question, it's directed to waterways for the most part. Wherever it does come into the collection system and comes down to the sanitary plant, we have a unique situation where we have a 21 million gallon detention basin, so if we really get a lot of fluid coming in here, we can actually bypass and flow it to the detention basin until the weather subsides and then we can go send it back to the treatment plant and treat it after the fact. We also have a netting system on a combined sewer overflows, so that we can catch floatables if we do have to bypass. That happens sometimes. If we get enough rain, and if it is heavy enough and comes down fast enough, then that will happen. But it happens very infrequently.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

> *We have some bioswales in new construction. I don't know how well this question actually pertains to us. It is an urban area. Truthfully, we haven't gone that route. There is very little of that here only because there are costs associated with all of that, and this city is not in the best of economic shape. We're struggling to provide services for its constituents on a normal basis. To go above and beyond, a lot of people would argue that you're saving money down the road, but there's a lot of aspects for making those types of changes. If you need the money upfront to make those types of changes, you just don't have that type of money. That's the situation here.*

So would it be fair to say that you believe there seem to be stronger priorities ahead of focusing on these types of issues?

> *You could put it that way, certainly. I mean, we aren't totally void of going green. We want all new construction that happens here, I can't remember exactly what it is based on, but we do require the bioswales, so that we can re-perk the soil. We even have an apartment complex that has a green roof downtown. The city has actually invested in a lot of tree plantings, citywide. It's a lot of federal and state money but they have done that. We have planted thousands and thousands of trees over the last ten years or so. But other than that, there is nothing that really comes to mind, because of the struggle that we're in here.*

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members or within the public works department?

> *Because of the stormwater management plan that we have in place, we actually retrofit our inlets so that they don't allow floatables from going into them. That's going a long way in preventing floatables and other materials from getting into the collection system and ending up in waterways. That's something the state makes us do, we have to do it, but it helps a lot. Although it is a catch–22, because although you prevent the floatables*

from going down, but what you're doing is catching these floatables up top when we have rain events. It can become disastrous, because now you have a clogged inlet where you most definitely need drainage and that doesn't happen. And then we get a call, so you're damned if you do, and you're damned if you don't. You protect the environment, but you're causing additional work for the sewer utility and you're raising the ire of constituents that aren't getting what they feel they should be getting anyway, because of the economic situation. So it's tough. As far as addition conversation goes with system improvements, we don't have much interaction with the administration.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

Outside of the financial, I don't think so. I can't speak for the administration, I don't know how green they are. I can't speak for them, and that would be the only other impediment. The money and the drive. And I don't know if the drive necessarily is or isn't there. They say do this and we do this. If it happens to be green, so be it. It basically boils down to economics, if we had the money, I'm sure we'd do some of it. I think we'd be leaning in that direction, certainly in this day and age.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

I don't know what to tell you on that score there because there has been a new administration that came in approximately a year ago. There's been a lot of turnover and I don't know who would spearhead that. I used to have names that I could probably pull out and give you, because we do have river marches annually, where everyone gets involved. The state, federally, and our local community gets involved and they get shirts and they'll walk around and pick up garbage for a day and then everyone goes away. We had a guy that spearheaded that and I'm sure that he had some other green ventures that he was involved in, but he's gone now. So I don't know what to tell you. In a nutshell, I don't know who is doing what now. I'm kind of isolated down here at the sewer plant; I'm not up at city hall.

That is understandable, you have given me some valuable information already and I do appreciate that.

> *Yeah, if you want my opinion, given the fact that we've lost a lot of personnel and not replaced it, and given the fact that we've lost a lot of funding and not replaced it; I think we're doing pretty well. We meet all state standards for stormwater management. Are we perfect? No, but nobody is. When we're required to do something, we do it. But nobody is doing anything out of the goodness of their own heart, though. It's just not there. We're not equipped and we're not funded for that type of thing, it is that simple. It all keeps going back to economics. We do what we can. Those retrofits on inlets do save a lot of floatables from getting into the waterways, and we're required to replace them on a regular basis. Anytime we go near an inlet to fix it or do anything to it, we have to either retrofit it with the device to prevent floatables from entering or we have to replace the whole head of it. That's a nice thing there, that does work, and it does help. Some of the things that you've described seem like they would happen on a small scale, and it would be hard to implement them on a large scale, is that correct?*

In short, yes. But the goal of green infrastructure, at least the as I see it, is to create a network of green space– such as bioswales and urban forests within a municipality. This may be the result of multiple smaller projects that may string together throughout the urban environment, whether it is in public space or vacant lots, to contribute to a larger good. The more green infrastructure there is, the more stress is relieved from combined sewer overflow systems as well as other additional public benefits– including the release of clean water into local waterways instead of water that may be loaded with pollutants. But yes, essentially it may involve stringing together numerous small projects to create a patchwork system.

> *Right, well that make sense to me, but another issue—or point I wanted to bring up is this. When we talk about these urban areas… a lot of times we're talking about poverty-stricken people who are not educated. So, from my experience, the higher in class and education you go, the more earth–friendly people become for some reason. I guess they're more knowledgeable so they try to do the right things. So that is a big thing to keep in mind when you look at cities on the river. A lot of times, these people are really struggling to live a good life.*

It is a tough situation, but a large number of these green infrastructure techniques are incorporated with parks and public space that anyone can access. There have been studies that open space, that have tree canopies and parks where people can go, raise moral, social well–being and also physical health. These things contribute to a higher quality of life. That is a major benefit of the sustainability movement. That being said, I think a large reason why implementing these practices does not take place is because of initial financial costs. But perhaps just as important of a reason is that people are unaware of the other benefits that green infrastructure can provide.

> *Well I can certainly vouch for that. Hell, I feel like I don't know what many of the benefits are. I don't think our administration is anti–green, our mayor is very park conscious. He's trying to spread that kind message, especially to the younger children. He's doing what he can, through parks and open space in the city. You know, to do the green thing. But in a lot of ways you're trying to get blood from a stone.*

It certainly seems like it is a difficult process. Do you have any other questions for me?

> *No, no. If you want to talk again in the future feel free to call me back and I wish you luck on your thesis project.*

Municipal Participant 4

Do you have any questions for me before we begin?

> *No, none whatsoever.*

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

> *In the simplest of terms, we haven't upgraded our existing system. The system we currently use drains runoff into either the canal or the other open water sources. Our requirement right now is to change catch basin grates to say that no wastewater is going*

to streams. Anytime we have new construction, that's what we have to update to. That's state mandated that we have to change our catch basin lids to state that the water goes to open water. No wastewater, no dumping, none of that stuff.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

Yes, there are a few areas of town that have used them. The big ones are the new developments. They have the detention basins. There is one little development that has permeable concrete. We mainly push to go that way, anyway. With stormwater regulations through the state, anyway we have to have a certain percentage of permeable areas according to your site plan.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

Just in new construction. The municipal utilities authority is updating their plan now. They're not allowing us to wash the public works vehicles with any soap or degreaser or anything. They're in the process of putting in a wash basin area for utility vehicles, where the water will be put into the waste pipe rather than just runoff. There, it will be treated with the rest of the wastewater.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

Well, there hasn't really been that much of a push for those types of management practices other than in new construction. As long as we're up to the rules and government mandates, a lack of funding really prevents anything above and beyond that. But the city does require those types of things in any new development.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Really, not a lot of people know about the stormwater management. You say stormwater management to some people and they may look at you and not have any idea what you're talking about. I guess the city engineers, but they're more involved in the regulations about stormwater.

Municipal Participant 5

Do you have any questions for me before we begin?

No, but I may as we go along.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

It is collected in catch basin through drain inlets. We pipe it from there and the water is ultimately channeled out to the river.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

No.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

No.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

There are two reasons. A restriction in available public property. And the other, and more important reason, is the financial end of it. I certainly wouldn't say that we are opposed to those types of management techniques, especially for future development, but there is really no need for it right now.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Community values? I would say our Mayor.

Municipal Participant 6

Do you have any questions for me before we begin?

No I don't, go ahead.

So the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

Basically, we just maintain what system we have in, as far as stormwater runoff we have. It's been around for years. Most of the new stuff that has been put in is up to date, environmental practices we use. But for the most part, it is largely maintaining the system we have.

Can you describe the current infrastructure the municipality uses?

Well, most of the stormwater goes straight to the river. The water from the streets goes to the river. And the new developments, a large majority of those go to stormwater ponds. But, well, basically all of our water just goes to the river.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

> *Well, we've been testing some rain gardens at the library and at the school which the stormwater enters before it goes to the river. They're fairly small. Those are relatively new. As far as anything else, there has not been any yet.*

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

> *Yeah, there has been a push by administration and amongst the city engineers for those sorts of things. Basically, anything new is leaning toward green infrastructure.*

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

> *Money. That's number one– money. That's the primary force on anything in any small town: money. The government mandates things, and a lot of times you don't have money to do it or enforce it. That's the main thing. You know, they'll mandate rules and want you to do things but they don't give you any money to do it. If the government doesn't give you any money, you have to keep asking your townspeople for money, and they just can't afford it after a while. Some of the green stuff is good, but some of it I think goes overboard. Taking care of streams, you know I think is good but sometimes people get carried away with it all. Now I do believe that we should be treating runoff– there are a lot of environmental issues there with the pollutants. Sometimes, you just don't have the money to do it.*

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

> *That's a good question. Probably our engineers or mayor or council members but a lot of these issues are mandated by state or federal anyway, so we don't really have a choice.*

Municipal Participant 7

Do you have any questions for me before we begin?

No.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

Delaware regulations for stormwater cover both quantitative measures and qualitative measures. We basically reflect what the state requires of us. The post–construction runoff has to meet the pre–construction runoff, as far as quantity is concerned. For quality, you pretty much have to treat the whole site and you have to achieve 50% reduction in sediment. In the city we have storm sewer systems. Runoff, a lot of it– I'd say 70%, goes through a stormwater facility, whether it is a dry pond or a wet pond or via infiltration or underground storage unit, or something. From there it goes either directly into the stream or into our storm sewer system. And the storm sewer system eventually discharges into the creek.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

Within the last two years, we have. The state has kind of changes the regulations which indicate, for quality control, they want to use green types of practices. So in the past couple of years, we have approved quite a few bio–filtration facilities. We have used bioswales. Infiltration practices, now, that's very hit or miss here in [the municipality] because we have very clayey soil in most cases. So, infiltration just doesn't exist. We usually require– wherever a stormwater facility will be, we usually require a geo–tech to come in and do infiltration tests. If infiltration is possible, then we require infiltration.

So utilizing green infrastructure to manage stormwater is the basis for new construction, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

> *Well, we try to utilize these techniques as much as possible. There hasn't been much discussion beyond that, it is basically our priority the meet the state regulations.*

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

> *Yeah, [the municipality] is pretty much built out. There are very few large areas that are being built. So a lot of our projects are taking infill type construction– taking a couple old buildings and tearing them down and building some new, higher ones. So one of the limitations for using any kind of quality control, really, is space limitations. These sites are so small, and they don't have that much room to put these facilities on them. A lot of them end up being underground storage. And the only way you can get green– or be qualified for being a green technique is you have to have infiltration. Otherwise it just goes in, you have a holding period just like a regular stormwater pond, and then it's released. So, site constraints and the soil conditions are the big things.*

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

> *I don't know if there is anybody within the city. We send out a survey every five years to poll the residents on our services, but stormwater is not included on that. I don't think anyone has a feel for stormwater, or how the community feels about stormwater management. We've got a substantial park system, so there is a high priority for having open space available to people, but that is not geared toward stormwater. I would say most people do not care about stormwater management unless their basements get flooded out. They just don't realize the importance of it. People they live along the creek right now, you know if we have a 100 year storm, some of them have problems with their basements and so forth. But if we didn't have so many of the stormwater facilities in the city, their properties and their houses could get flooded out completely. They just don't*

realize that. I'll tell you the people that live along the streams are more apt to care about stormwater but the people that live in the center of town that have to shell out money for the maintenance of their stormwater facility– if they didn't have to pay for it they wouldn't want to pay for it.

Municipal Participant 8

Do you have any questions for me before we begin?

No.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

Well [this municipality], like many cities in Pennsylvania in the East is very old is very old. Our infrastructure is very old. Much of our stormwater collection system was built in the early 1900s. There have been a few projects since then that have added to it, but for the most part, that system was virtually completed by 1920. There are some rather unique construction styles within that system; some very large pipes– eight feet to, the largest one is fourteen feet in diameter. They are concrete but then brick lined on the inside. And if you think back to that time in history, that construction was done by hand and with some very unsophisticated equipment. So, it is very unique but it is also very old and it is showing its wear. It is showing its age. There have been a few projects to supplement it, to replace parts of it; but there just isn't that much money around for projects of that magnitude. As you can imagine, it is very expensive.

Does [the municipality] have a combined sewer overflow system?

We do not. Believe it or not, the [municipality] way back when had the good sense to design two different systems; storm and sanitary sewers. Now, I'm not naïve enough to say that there isn't some interconnection, but it is not designed that way, and I couldn't

tell you a definite location if there is one. Certainly, it is not designed to have interconnections.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

The answer is yes. We have a relatively new stormwater management ordinance; it's about two years old. That ordinance provides for all of the things that you mentioned. As new projects come about through the city, there are green methods being implemented. Not by the city, but by developers. There was one interesting project for us. Back ten years ago, Hurricane Allison came through the area and blew out a dam at [the local] lake. It blew out the dam, and of course our thoughts at the time were that we had to rebuild the dam. We actually went through getting a professional design done, and we went through the bidding process. The bids were much higher than the cost estimates were. So at that time we decided to look into what else could be done. We decided not to replace the dam since really the only use of it was recreation. We decided not to replace it and kind of let nature take its course. We designed an environmental park. It has wetlands, meadows, and we redid all of the stream banks and let the stream go back to its original course from 150 years ago. That park is very, very successful. We have all kinds of natural habitats there now, and it's worked well. We have built about a two acre wetland area, and that does help with the stormwater.

So new development is required to use techniques like bioswales, but in the older city– it is still primarily to get the runoff in the pipe and send it downstream?

Yeah, yes.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

Yes, we're actually going through the process of forming a stormwater utility. [The municipality] is in some serious financial situations. We're in bad shape. In order to

generate some revenue and be able to have some money to use on the stormwater, we're forming a stormwater utility. Studies are underway to make that happen, to determine what the assessments might be on various property owners. What it does is it will encourage property owners– and it will apply to big commercial properties and industrial properties that are mostly impervious. They will have the option of installing some green measures, and they will get credit toward their stormwater assessment by doing that. So they will actually pay less, and in exchange they will have to install some green measures. So that's pretty far along, but it is not adopted yet. We're hoping that by the end of the year it will be in place, so that it is fully up and running next year.

You've mentioned the financial barriers. Are there other barriers that you foresee preventing or delaying the inclusion of green stormwater infrastructure in your community?

Not really. The only other thing that may anchor in, although it may be somewhat mild I guess, is that anytime in this area you try something new– people rebel and say "Well, that's not the way we always did it." We'll certainly get some of that reaction. But, that's not the end of the world.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Our mayor would probably have a pretty good feel for community reaction. His name is _____ . It's kind of hard to say. [The municipality] also has a very strong Latino population, it might be interesting to get their side of the issue. We do have a councilman who is Latino, and it might be good to talk to him. Slightly different viewpoint. His name is _____.

Municipal Participant 9

Do you have any questions for me before we begin?

Nope.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

> *Well we are mainly a sewer authority. We have a combined sewer system, so we're partially combined and partially separated so we do have stormwater and rainwater entering our sanitary sewer system.*

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

> *No.*

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

> *Some of them, we did a separation project about 5 years ago. Part of the project was to separate the stormwater from the sanity on residential homes and some commercial buildings. We've been dealing with the County Conservation District and have presented some information to home owners about doing rain gardens and some things like that, like rain barrels. There has been an effort to incorporate things like that, but nothing is in place right now.*

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

> *Right now there is a lack of space in a lot of the areas as it is urban, and then also the cost. Homeowners don't want to spend extra money to treat the stormwater. They just want us to take care of it. So those would be the two biggest factors, I believe.*

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

You could contact the city administrator, he would probably help you out on those questions there.

Municipal Participant 10

Do you have any questions for me before we begin?

No I don't.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

The [city] is under NPDES permits, because of the size of the city, we've been doing this for quite a few years now: we have an extensive stormwater system throughout the city and have a couple of discharge points. We actually take water samples and have them tested where they discharge into streams. We have a number of streams that run through the city, <proceeds to list the streams>. We collect the samples, what we test for offhand? I'd have to go to the actually people who do the testing and ask what they are. Through the years we have been installing what we call a "snout". It is a cover that goes over the discharge pipe and inlets. It helps catch debris in inlets, and as new developments come through, we ask them to install those also.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

We have a few bioswales. There is not a great deal of development in the city because we're fairly well built out. But there have been a few developments where we have required the bioswales to go in. Other than that, we don't have a whole lot. We are in a karst geology, so infiltration, depending on where we're at in the city, we're limited to use infiltration. We have about four different water sources, one of our water sources is

<provides spring name> and that aquifer extends under our downtown area. So, we basically don't ask for or even like if they put infiltration in those areas.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

Yes, we recently went to see a green roof that was installed several years ago near the city. The purpose for the visit, why we wanted to go see that, is I am looking at city–owned buildings that would perhaps be good candidates to install green roofs on. From both a water-quality perspective and for the energy efficiency, I'm trying to help insulate the buildings for heat and cooling. We don't have any concrete plans in place yet, but I am in an investigation process to look to put green roofs on. I would like to put them on our city hall and public safety building, they have big roofs. What I'm concerned about is adding all that bed load to the roof, I may have to increase the structure to do that, so it may become cost prohibitive, to do it on those two buildings. In fact, the one that we did look at, they were telling us that we had gotten a pretty good rain storm and there was a lot of water being held in the soil on that building, and they actually started getting some buckling in the building. When the architect did it he accounted for all of the normal loads but did not account for the fact that the soil was going to be saturated. Another thing, in addition to the green roofs that we're looking at is doing some bioretention along the streets. We have a project that we're working on right now, but we have limited funding on it, so I don't know if we'll be able to get it included into this project. I would like to include some bioretention areas along a roadway project that we're doing. It's an existing collector road. We're also in the process of updating our subdivision and land developing ordinances and putting in a requirement for bioretention in new subdivisions. Also looking at where we've rebuilt streets to add porous pavement. A main reason why we're looking at that is because there are definitely areas in the city where we could do it, but there are certainly areas where we cannot do it because of the geology. But I think there are areas where we can do it, significant areas.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

The biggest one would be in the infiltration, because of the karst geology. Other than that, the costs certainly come into play, but in my mind that is minimal compared to the infiltration of water into a karst geology.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

I would certainly be one, I answer directly to the mayor. Most of the stormwater responsibilities fall under my occupation.

Municipal Participant 11

Do you have any questions for me before we begin?

No, go ahead.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

Infrastructure wise, the planning board reviews any new building or anything like that that comes in. Federal and state law, you know there are certain guidelines that need to be followed, they'll do that part. As far as our part, we maintain all of the basins that we have, we maintain all of the stormwater inlets– we clean them yearly. As per the rules, we have less than one thousand storm drains in the city, so we have to clean them all each year. As far as everything else goes, we're always looking toward ways to improve water flow, you know especially after these last couple storms. It's opened our eyes, we've never really had this kind of water before. There are some things that we need to work on, you know, like stream management and stuff like that.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

I think that the planning board is just getting into that stuff. Most of our water just goes into different streams. As far as if you're asking me if we're going green… the old stuff is obviously not. Anything new, I'm sure the planning board is looking at it. One of the things that they're trying to do is this concrete where the water will go right through it. So porous concrete, where the water will go through it, rather than digging basins and stuff like that. So the porous concrete has layers underneath it so the water can be dispersed into the streams at a different rate than having regular concrete, where it'd wash into a basin and then slowly gets washed in. But right now, most of the water is just piped or directed into basins. A lot of the basins have a three inch opening or four inch opening to let the water into the streams. I, myself, thought was kind of crazy when they first came in here until I started seeing some of these big storms we've had where it does help out as far as washouts and stuff like that. You see a lot of older parts of the state where this stuff isn't being done and you see a lot of bridges being washed out. You know, it definitely has its place.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

Yeah, we have. I deal with the engineers and we've talked about some of those different things to get the water where it needs to be. Rather than just putting a storm drain here and getting rid of the water– we think about how we can get the water into the forest and how we can get it back into the ecosystems.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

Well I think probably the cost. You know, none of this stuff is cheap. You know porous concrete is probably two to three times the cost. Anything new coming out, I'm sure at first, will be more expensive. So cost would be the biggest thing.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Probably our engineer with the technical stuff.

Municipal Participant 12

Do you have any questions for me before we begin?

No, I think we're alright.

Okay, so the first question is… How does the municipality you work for manage stormwater? Specifically, can you describe the infrastructure of the system?

The stormwater collection system that we have basically collects the water and discharges it into different water bodies throughout the city. It is separate from our waste water system.

Does your municipality utilize green infrastructure to help manage stormwater? Examples may include urban forests, permeable paving, rainwater harvesting, green roofs, rain gardens, bioswales, and constructed wetlands.

Yes in the last couple of years we've been involved with constructing wetlands along the river. The DEP had allocated over 20 million to the county last year to restore wetlands throughout the county, and a small portion of that money has been used within the municipality. Now, I should be clear that this is not something we've directly been doing, but there is one large industrial company in town that received some funding. I believe they actually brought in a professional landscape architecture consultant to design some wetlands along the river. They do help out with stormwater somewhat, but it is a private project. We have implemented some smaller wetland projects on our publicly owned land, but that was a larger project.

To you knowledge, have there been discussions of utilizing green infrastructure to manage stormwater amongst municipal board members?

Yeah, I do believe there have been increasing discussions, especially coming from our municipal engineer. But we're primarily focused on maintaining the existing system because we're a relatively small city and there isn't much new construction going on.

What barriers do you believe prevent the inclusion of green stormwater infrastructure in your community?

The only thing that really comes to mind is the cost.

Who, in your opinion, are the decision–making individuals that be most informed of the community values related to stormwater issues in your municipality?

Yeah you could contact the municipal engineer, but I'm not sure she'd be that tuned into the community values aspect of it. But she would certainly know more of the technicalities.